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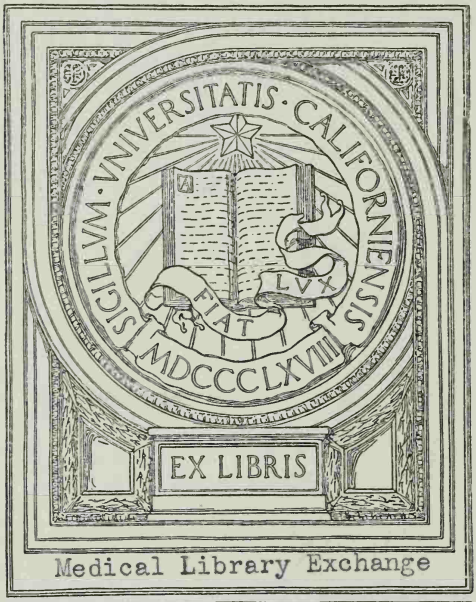

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SURGERY
OF THE
BLOOD VESSELS

SURGERY

OF THE

BLOOD VESSELS

BY

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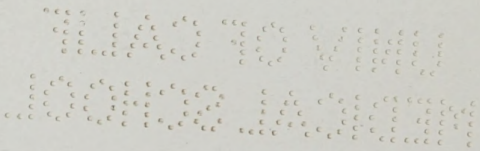

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PREFACE.

To no department of surgical endeavor have Americans contributed so largely in recent years as to blood-vessel surgery. The first successful end-to-end suturing of a divided artery in man was done by Murphy, of Chicago, in 1897, when he united the femoral by his invagination method. The revolutionizing treatment of aneurisms by Matas, who devised endo-aneurismorrhaphy, is considered the most important advance in the therapy of this disease since the days of Hunter. The development of transfusion of blood by Crile, of Cleveland, is another notable instance of the large share Americans have had in the progress of blood-vessel surgery. Halsted, of Johns Hopkins, introduced the principle of partial or gradual occlusion of an artery by means of malleable metallic bands. Finally, Carrel, an American by adoption, and his former associate, C. C. Guthrie, have carefully worked out the technique of blood-vessel suturing and were the first to place it on a stable basis. A monograph dealing with the various phases of blood-vessel surgery, and particularly with its recent developments, may prove of some interest in a country that has contributed so largely to its progress.

It has been the aim of the author to present the scientific and the laboratory features of vascular surgery and particularly its practical aspects that may be of interest both to the surgeon and to the general practitioner. Therefore the treatment of hemorrhage, pathologic and traumatic, and such subjects as aneurisms, thrombosis and embolism, congenital nevi, varicose veins, and hem-

orrhoids are described as well as the history and technique of suturing blood-vessels and transfusion of blood.

Probably the most interesting surgical reading is an account of personal experience and original research. Whether the reader approves of the work or not, it may at least present the subject in a new light. It is for this reason that a good portion of the book is taken up with the original work of the author, who is fully aware that the importance of what he has done is not in proportion to the space it occupies. His methods of end-to-end suture of blood-vessels, of transfusion of blood, of lateral suture of blood-vessels, of suturing arteriovenous aneurisms, of making an Eck fistula, of transplantation of the anterior temporal artery, and of resection or transplantation of intestine after embolism of the mesenteric arteries are therefore described in considerable detail.

It is a most pleasant duty to return thanks to the surgeons who have invited the author to demonstrate his method of suturing blood-vessels at their clinics, or in their laboratories. Among them are Dr. Donald Balfour, of the Mayo Clinic, at whose invitation the author performed a transfusion of blood; Dr. A. A. Law, a similar operation being done at his request at the University of Minnesota Hospital; Dr. W. L. Rodman, by whose courtesy the author lectured on blood-vessel surgery and demonstrated his method of suturing blood-vessels at the Medico-Chirurgical College, of Philadelphia; Dr. A. D. Bevan, who kindly arranged for a demonstration of this technique on animals at the Rush Medical College; Dr. J. Frank Corbett, at whose invitation the technique was demonstrated on animals in the laboratory of experimental surgery at the University of Minnesota; and Dr. H. A. Royster, by whom the author was invited to demonstrate his method of suturing blood-

vessels on animals at Raleigh, North Carolina, before the medical society of which Dr. Royster was president. There are many others whose suggestions and words of encouragement are deeply appreciated.

Naturally, many books and journals have been consulted in preparing this book. In the chapters on the history of blood-vessel surgery and of transfusion an effort has been made to follow the chronologic order and references have been given only when the literature was quite recent or where for some other reason it seemed advisable. The author feels particularly indebted to the section by Matas, in "Keen's Surgery," on aneurisms, which has been freely drawn from; to Crile's work, "Hemorrhage and Transfusion"; to Warren's "Healing of Arteries"; to the monographs on blood-vessel surgery by Guthrie and by Bernheim, and to various papers by Stephen H. Watts.

To Miss Helen L. Lorraine, the artist, a pupil of Mr. Max Brödel, the author is greatly indebted for her excellent drawings.

The publishers, The C. V. Mosby Company, at whose suggestion this book was written, have extended many courtesies that are deeply appreciated.

J. S. H.

January, 1915.

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SURGERY OF THE BLOOD-VESSELS

CHAPTER I.

THE STRUCTURE AND HISTOLOGIC REPAIR OF BLOOD-VESSELS.

A knowledge of the histology of blood-vessels is necessary for a proper appreciation of the healing of blood-vessels. Blood-vessels are described as having three coats: an inner, or tunica intima; a middle, or tunica media; and an external, or tunica externa, or, as it is usually called, adventitia. While these coats are to a greater or less extent present in most blood-vessels, their arrangement and their relative proportion vary very greatly. The tunica intima consists of vascular endothelium, which is supported by a variable amount of fibro-elastic tissue, the elastic tissue predominating. The capillaries consist practically entirely of the tunica intima, which in this instance amounts to but little more than the endothelial lining. The middle coat, or tunica media, is a mixture of smooth muscle, elastic tissue, and fibrous tissue; while the adventitia, which is very strong but generally thinner than the middle coat, consists of fibro-elastic tissue. The essential coat of the blood-vessel is the inner coat, or tunica intima.[1]

In arteries the endothelium of the intima is made up of flat, spindle-shaped cells joined together irregularly by

[1] Piersol: Human Anatomy, Vol. I.

a kind of cement substance that is shown by silver staining. Where these cells come together there are occasionally stigmata or points where the junction of the cell is less accurate than usual. The sharp outlines of the endothelial cells are less marked in capillaries than in larger vessels. A small oval nucleus in the endothelial cells can be demonstrated (Figs. 1 and 2).

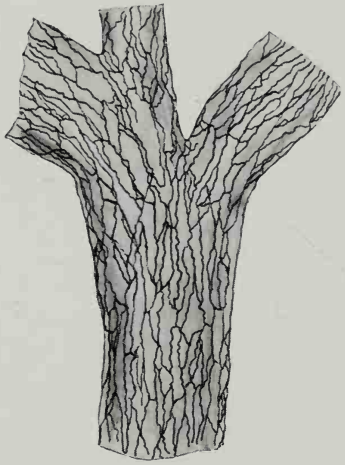


Fig. 1.

Fig. 2.

Fig. 1.—Endothelium of arteriole after silver staining. x 200. (After Piersol.)
Fig. 2.—Endothelial cells more highly magnified. x 500. (After Piersol.)

The involuntary or smooth muscle varies greatly in amount. It may form a thin or imperfect layer in the arterioles, or a thick coat in the larger arteries. It is most abundant in arteries of medium size, where it is found in broad bundles between fibers of elastic tissue. In veins there is but little muscle and sometimes it is entirely wanting.

Connective tissue occurs as fibrous and elastic tissue. Elastic tissue is very conspicuous in all of the arteries except the smallest and is found to a considerable extent in veins. It is very abundant in the larger arteries and,

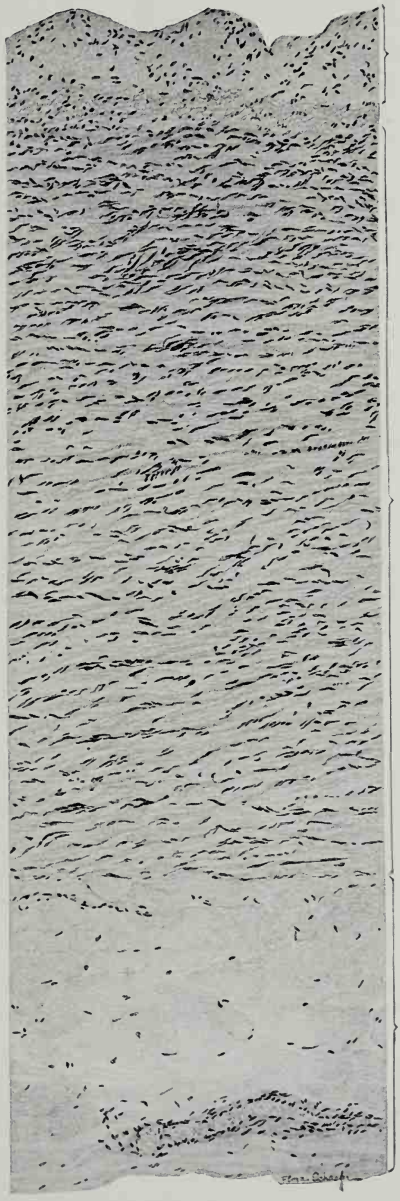


Fig. 3.—Drawing of transverse section of aorta. x 120. (Original.)

as has already been mentioned, forms a basement membrane for the endothelium of the intima (Fig. 3).

All of the larger vessels are provided with minute nutrient vessels which usually come from some neighboring artery and are distributed in the adventitia of the blood-vessel. They are called vasa vasorum. Lymphatics and nerves are also found in the outer coats of the blood-vessels. The plexus of nerves that surrounds arteries is particularly abundant. Small nerve fibers from this plexus enter the media and are distributed among the muscle cells. These nerve fibers are chiefly motor in function and are a part of the great vasomotor system. Sensory nerves undoubtedly occur quite constantly accompanying the vessel wall. This is frequently demonstrated in operations under a local anesthetic when the clamping of a blood-vessel will cause pain even though the surrounding tissue appears to be free from sensation.

In an artery of medium size, about half a centimeter in diameter, the intima is seen in section as distinctly corrugated, which is due to the fact that the vessel is collapsed and the internal elastic membrane draws the endothelial lining into folds. Under normal pressure when the artery is functionating these wrinkles would be smoothed out. The intima in such an artery consists of a layer of endothelium that rests on a thin layer of fibrous and elastic tissue and this upon the elastic membrane, the total thickness being very small in proportion to the thickness of the other coats. The tunica media, or middle coat, is quite thick and comprises more than one-half of the total thickness of an artery of medium size. It consists of smooth muscle and elastic and fibrous tissue. The external layer of the middle coat is an elastic membrane called the external elastic membrane, which is similar in construction to the internal elastic membrane

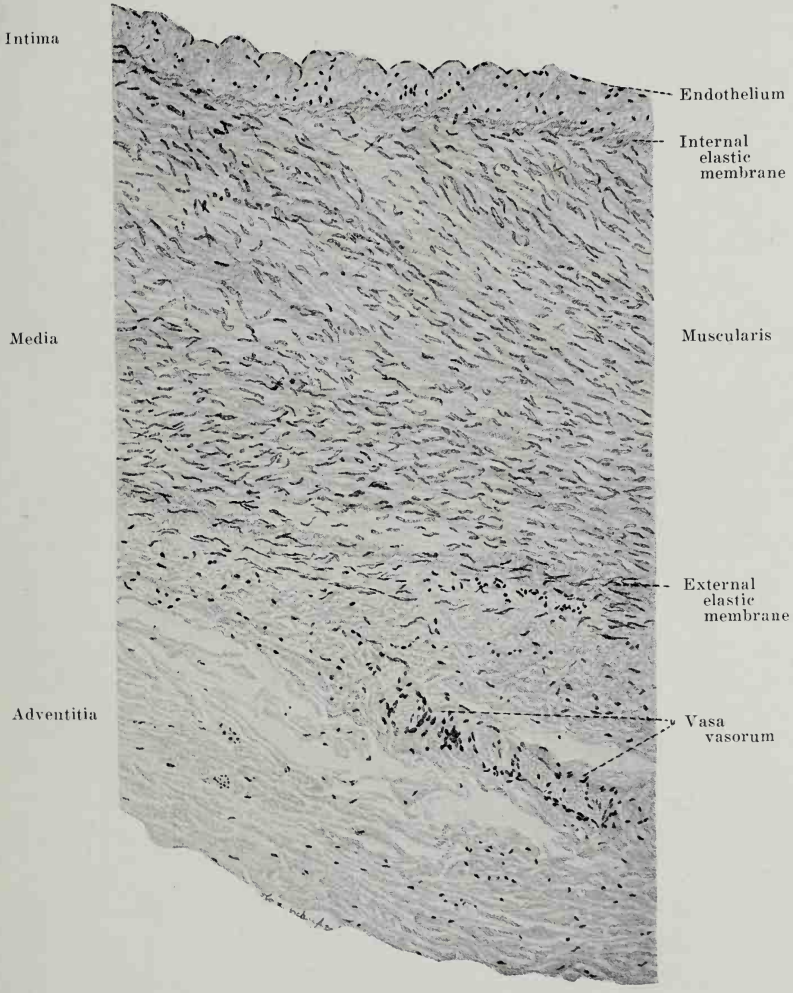


Fig. 4.—Drawing of transverse section of an artery of medium size. x 120. (Original.)

of the intima. The adventitia is thinner than the media but is exceedingly strong. It is a mixture of fibrous and elastic tissue and contains the vasa vasorum, lymph channels, and the plexus of nerves. As the artery decreases in size, all the coats except the intima diminish. The internal elastic membrane disappears first, then the media. Just before the vessel becomes a capillary the meager amount of muscle cells disappears. In capillaries practically nothing is left except the endothelial lining with a small support of connective tissue.[2]

As an artery of medium size becomes larger, the intima and media increase in bulk and the boundary between these two coats becomes less marked, for the elastic tissue is a more prominent feature of the middle coat which gradually blends with the internal elastic membrane. The muscular tissue in the media is largely replaced in large arteries by fibro-elastic tissue. The adventitia is somewhat increased and consists of fibro-elastic tissue as in smaller arteries (Fig. 4). It is exceedingly strong. Near the heart some muscle cells resembling cardiac muscle may run up for a short distance into the aorta or pulmonary artery.

Veins are always thinner than arteries and contain less muscular and elastic tissue. In a vein of medium size (Fig. 5) the intima is of somewhat the same construction as in an artery of similar size, except that the endothelial cells are broad and short instead of being long and spindle-shaped as in an artery and the layer of elastic and connective tissue is much thinner than in an artery. The internal elastic membrane of an artery of medium size is practically lacking in a vein of similar caliber. In the tunica media, muscular tissue is scanty. The media is altogether much thinner than in the artery and is dis-

2 Piersol: Human Anatomy, Vol. I.

tinctly deficient in muscle cells as compared with an artery. The adventitia of a vein is frequently thicker than the media and is of similar construction to the adventitia of an artery. In the lower extremities the veins often contain muscle cells arranged longitudinally.

The valves of the veins consist of pairs of crescent-shaped folds of intima. They form pockets that look toward the direction of the blood current in the vein, and

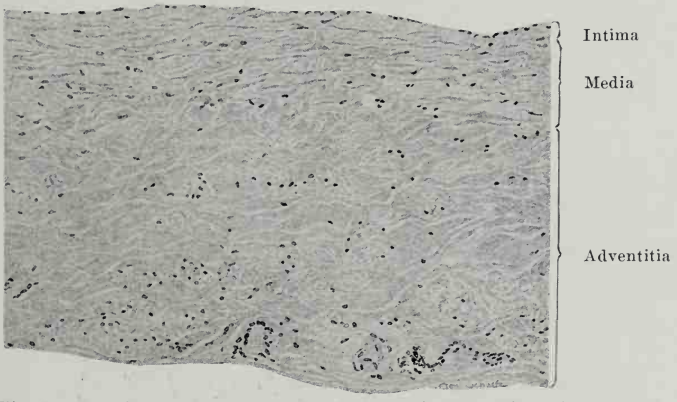


Fig. 5.—Drawing of transverse section of a vein of medium size. x 120. (Original.)

when filled the sides of the valves come together and prevent the reflux of blood.

In large veins the media is chiefly increased by the appearance of more elastic and fibrous tissue, though in the splenic and portal veins much muscular tissue is in the media. In the larger veins the adventitia is markedly increased and often, as in the vena cava, contains longitudinal bundles of smooth muscle.

The small veins have only endothelium and connective tissue. Approaching the capillaries, the connective tissue decreases, leaving the endothelium alone.

The capillaries consist of an endothelial coat with thin walls that favor the passage of the blood plasma into the

surrounding tissue. The endothelial cells are elongated cells with oval nuclei. Stomata do not occur in the walls of the capillary. Blood cells gain exit between the endothelial cells. In capillaries of the choroid, liver, and the

Fig. 6.—The carotid artery of a dog which was divided and sutured and the specimen removed eleven days afterwards. Note the silk which on the surface is completely buried by a thin layer of endothelium. Magnification, 65 diameters.

glomeruli of the kidney the endothelial lining seems to be continuous as a kind of syncytial layer.[3]

The healing of blood-vessels after ligation has been a subject of study by surgical pathologists for many years

3 Piersol: Human Anatomy, Vol. I.

and the literature on this subject is abundant. Healing by the so-called organization of a thrombus, accompanying injured intima, and by a mere approximation of the intima has been investigated experimentally and

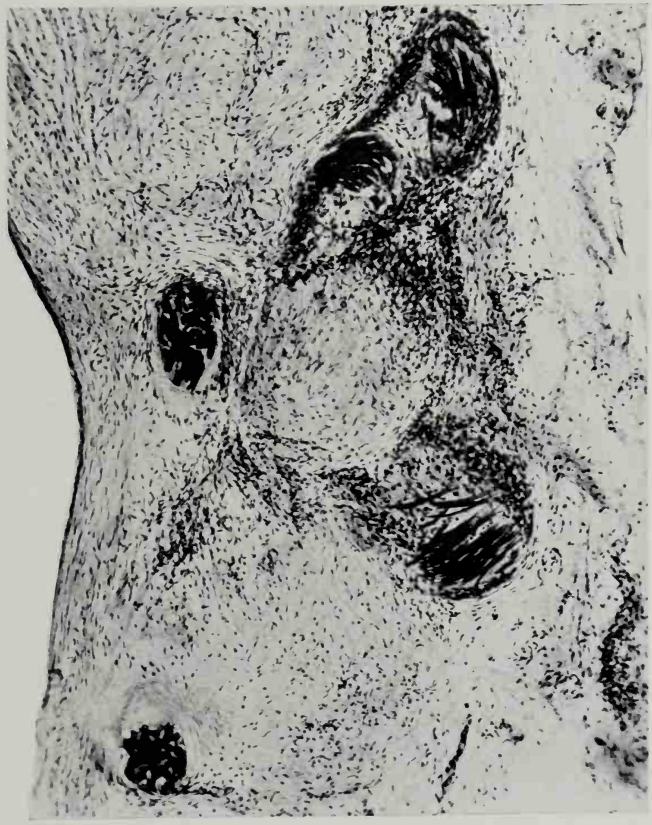


Fig. 7.—Microphotograph of a carotid artery of a dog which was divided and sutured and the specimen removed 173 days after operation. Note the partial regeneration of the coats of the vessel and the well covered silk. Magnification, 85 diameters.

clinically in many works and has been studied with particular care by J. Collins Warren in a monograph, "The Healing of Arteries," published in 1886. The healing of arteries, however, of chief interest in modern vascular surgery is that which follows suturing and

not the ligature. In successful arterial suturing repair in the course of time is complete. The accompanying microphotographs show that the suture material is covered with endothelial lining and the middle and outer

Fig. 8.—Microphotograph of union of artery and vein sixty-three days after operation. The section was somewhat torn in cutting but the silk can be easily seen covered with a layer of endothelium. Magnification 57 diameters.

coats have begun to regenerate even a few weeks after the suturing (Figs. 6, 7 and 8). In older specimens studied by other experimenters the repair is complete. Matas [4] says that repair which follows a properly sutured

4 Keen's Surgery, Vol. V, page 138.

wound in an artery "is equivalent ultimately to a complete and perfect regeneration of all the histologic elements which enter into the formation of the arterial wall, the elastic and muscular elements being reproduced as perfectly as the baser elements, if the specimens are examined long enough (at least one hundred days in dogs) to allow the regeneration of the elastic and muscular tissue to be complete." He further says that "clinical experience fully confirms the histologic possibility of the complete regeneration of the vessels." An extensive inquiry made by Matas failed to show that any aneurism has formed at the site of a previous suture.

Thomaselli[5] studied the histological process of healing in transverse wounds of the blood-vessels. He says the muscular layer is completely regenerated, and the elastic fibers of the media are regenerated and are more numerous along the scar and near the lumen. They do not form a true inner elastic membrane but practically replace it. The elastic fibers in the adventitia are not regenerated, the new adventitia consisting of connective tissue. Close to the sutures there is entire restoration of the three layers, though the muscle cells and elastic fibers are hypertrophied.

De Gartano reported perfect restoration of all the vessel wall, including the elastic fibers. Stephen H. Watts, after histologic examination of sections from sutured blood-vessels, says that at periods of from twenty-eight to eighty-two days after operation there is a gradual restoration of the artery at the site of suture and all the elements of the vessel wall except the inner elastic membrane are probably regenerated.

E. Archibald Smith[6] states that, as the immediate re-

5 Clinica Chirurgia, 1902, No. 6, and 1903, XI, No. 5; Central. fur Chirurgie, XX, 1906.

6 Suture of Arteries, Oxford University Press.

sult of suturing arteries, necrosis occurs in that portion of the wall of the blood-vessel subject to the direct pressure of the stitch. This includes all of the elements, though the elastic tissue withstands more pressure than the muscle or the fibrous tissue, as determined by the fact that elastic tissue reacts longer after special stain. In the center of this small area of necrosis is a microscopically narrow cleft that opens into the lumen of the vessel and contains a small thrombus. This thrombus in successful vessel suturing does not protrude to a perceptible extent into the lumen of the vessel. A small amount of such thrombus is necessary for complete hemostasis as is more fully described in the chapter on technique (page 46).

According to Smith, from the end of the first week granulation tissue is present in the neighborhood of the wound in the vessel. Many new capillaries and fibroblasts invade the sutured area from without and in this manner the fibrin is absorbed and disappears in ten days. Long before this time, however, endothelium has grown over the fibrin deposited around the sutures and furnishes a complete endothelial lining for the vessel. The numerous small capillaries gradually disappear and new spindle forms and fibrous elements are seen. Last of all occurs the formation of specific tissues, of new elastic and muscular elements, in the young scar. This happens from three to four months after operation and follows the normal histologic layers. Elastic tissue appears as extremely delicate fibers. At this time the suture material exists as a small remnant, being partly disintegrated by the granulation tissue and gradually pushed away from the lumen of the vessel.

CHAPTER II.

THE INDICATIONS FOR BLOOD-VESSEL SUTURING.

The marked attention paid to surgery of the blood-vessels in recent years has excited unusual interest and has been the cause of many extravagant statements, particularly as regards suturing blood-vessels. The sensational articles that have appeared in the public press have been to a large extent unwarranted, though the modern method of suturing blood-vessels is one of the great advances in surgery. As is stated in the work by C. C. Guthrie on "Blood-Vessel Surgery," "Heterografts succeed at first, but inevitably fail after the first few weeks. This is the disappointing but unanimous conclusion of experimenters. Thus there is, at present, no temptation for the enthusiastic surgeon to try and graft one lobe of the thyroid or a kidney taken from a healthy donor. The poor man will not be tempted to exchange one of his sound kidneys for so much hard cash." Lexer[1] says that even in animals transplantation of limbs promises practically nothing, "since, besides ischæmic inflammation and contraction, it is followed by hemorrhagic infiltration and nerve disintegration."

The idea that a new limb can be transplanted and will remain useful, or that a kidney or thyroid can be grafted from one individual to another, is erroneous. These experiments even in animals have not been permanently successful. A kidney transplanted from one dog to an-

1 Annals of Surgery, August, 1914.

other may functionate for awhile, but sooner or later the fine differences of serum and tissue destroy the organ and prevent ultimate success. However, while complicated glands cannot be transplanted, simpler tissue can often be permanently grafted from one animal to another, or particularly from one portion of an animal or person to another portion of the body. The simple function of a transplanted blood-vessel can be maintained and it is probable that at least the endothelial and connective tissue of the transplanted vessel is permanent.

The modern suturing of blood-vessels has five distinct fields aside from the older method of ligation: (1) The treatment of wounded blood-vessels. Here direct suture can be used, or if much of the vessel has been injured a segment of some vein from the patient's own body, as the saphenous, can be sutured into the defect. (2) Excision of malignant tumors that have heretofore been considered inoperable because of involvement of a large blood-vessel. A section of the vessel can be removed and the vessel repaired as after trauma. (3) Aneurisms can be treated in a similar way, though on account of the diseased condition of the vessel wall in spontaneous aneurisms, suturing is not likely to be quite so satisfactory as in traumatic aneurisms. However, several successful cases have been reported where spontaneous aneurisms have been excised and a segment of vein substituted. (4) Transfusion of blood. This can be done by a variety of methods, but the union by sutures if properly done is probably the most satisfactory method of transfusing blood. (5) Reversal of the circulation may have a limited field.

CHAPTER III.

HISTORY OF BLOOD-VESSEL SURGERY.

Surgery of the blood-vessels began with the first efforts to staunch the flow of blood and is probably the most venerable of any branch of surgery. Warren [1] gives the first recorded use of the ligature as occurring in 1500 B. C., when Susrutas employed it in tying the umbilical cord. But no mention is made by Susrutas of its use in surgery, nor do the early Egyptian writings say anything of the ligature. The Alexandrian school probably employed the ligature but the records of this work were in all likelihood destroyed when the library was burned. Aulus Celsus (25 B. C. to 45 A. D.) who lived about the beginning of the Christian era recommended the ligature in surgery in certain cases. Celsus was classed by Pliny as a man of letters (auctor) rather than a doctor (medicus), and was ignored by the Roman practitioner of his day. He wrote very extensively on medical subjects. His seventh book is surgical and contains probably the first account of the use of the ligature in surgery. It is doubtful, however, if his recommendations were put into very extensive practice by his colleagues. Galen (131-211 A. D.) mentions the ligature frequently. He was not a practical surgeon and avoided the use of the knife unless as a last resort. He used silk and linen and tells where he obtained his ligatures, at "the shop on the Via Sacra between the temple Roma and

1 Healing of Arteries, Wm. Wood & Company.

the Forum." Antyllus, in the third century, not only used the ligature but devised an operation for aneurism which still bears his name—ligating the artery close to the aneurism, both proximally and distally, and incising the sac. This method has given remarkably good results. Paulus Ægineta (625-690 A. D.) mentions the ligature often. Torsion is not referred to by him though it was described by Oribasus (326-403 A. D.) in connection with an operation on hernia. The actual cautery and various styptics were generally used to control bleeding. Rhazes (850-922 A. D.) and Abucasis (1106) used the ligature, but preferred as a rule styptics and the actual cautery. The latter wrote a book on the cautery.

Ambrose Paré revived the use of the ligature and in 1552, wrote earnestly advising its employment. He used a mass ligature, without attempting to isolate the vessel. The ligature did not come into general favor, however, for more than a hundred years after Paré's time. Even his pupil and friend, Guillemeau, often employed the cautery. When we consider that the ligature of Paré was employed *en masse*, including the adjacent nerves, and that sloughing and suppuration nearly always followed, and often secondary hemorrhage, we can readily understand why surgeons were not enthusiastic about this method of controlling hemorrhage. It is interesting to note that the reputations of the three surgeons, whom Garrison [2] selects as the greatest surgeons of all times,—Ambroise Paré, John Hunter, and Lister,—are founded chiefly or in large part upon the use of the ligature.

John Hunter (1728-1793) devised the principle of treating aneurisms due to arterial disease by means of a single ligature applied on the proximal portion of the artery at some distance from the sac, at a point where the artery

2 History of Medicine, W. B. Saunders Co.

was supposed to be healthy. Guillemeau (1594) and Anel (1710) had used the single ligature close to the aneurism, and Antyllus two ligatures, proximally and distally, and an incision into the sac. Waldrop (1782–1869) employed the ligature distally in treating aneurism, though Pierre Brasdor (1721–1797) first suggested the use of a distal ligature. In this way all combinations for the application of the ligature were exhausted and a new treatment for aneurisms must be based on something other than the ligature.

The history of the suturing of blood-vessels is of much more recent origin than the history of ligation. Hallowell, an English surgeon, first sutured the brachial artery in man in 1759. This was suggested to him by Lambert. In 1772, Assmann, of Groningen, after unsuccessful experiments on dogs, announced that suturing arteries was not feasible. This opinion apparently held good for more than a hundred years as Gluck, in 1881, was one of the first to renew efforts to repair wounded blood-vessels. Gluck found the sutures would often pull out and employed small ivory clamps to close the wound, leaving them in place. He had some successful results.

In 1879, Eck, a Russian surgeon, probably first accomplished the union of two blood-vessels when he established a communication between the portal vein and the vena cava, which is now known as Eck's fistula.

Von Horoch, in 1888, experimented with suturing arteries, using silk and catgut, but thrombosis resulted after all his experiments. In 1889, Jassinowsky, after twenty-six experiments on the lower animals, attained considerable success in repairing variously shaped wounds of the arteries. In many of his experiments the bleeding from the wounded vessel was controlled and its lumen was preserved. Twenty-two of the twenty-six experiments were

successful. He used fine curved needles and fine silk and did not penetrate the intima. The sutures were interrupted, and about one millimeter apart. He recommended thorough asepsis, smooth edges of the wounded vessel, and penetration of only the two outer coats. His research is one of the most important in establishing arterial suturing.

Robert Abbe, of New York, published in 1894 the results of his experiments in which he divided an artery and united it again by suturing the ends over a thin glass tube. In 1896, Briau and Jaboulay attempted experimentally to unite the divided ends of an artery by an interrupted mattress stitch that penetrated all coats and everted the intima. The experiments were not very successful. They did ten operations on the carotid arteries of dogs, and all of the vessels later became thrombosed. Afterwards they tried the same method on the carotid of a donkey with perfect results.

John B. Murphy, in 1897, published a method by which the proximal end of an artery was invaginated into the distal end by means of two mattress sutures, which were inserted so as to draw the proximal end into the distal end. This materially diminishes the caliber and can only be done in large vessels. Of thirteen experiments, three were successful. Murphy reports one case in which this operation was done for a wound of the femoral artery. After the operation was completed there was no leakage and pulsation appeared in the artery below the point of union. The patient made a good recovery. This is the first successful end-to-end union of an artery in man.

In 1897 and 1898, Silverberg experimented with arterial suture in dogs. He used the finest silk and, with three exceptions, employed the continuous suture instead of the

interrupted. He did not attach much importance to the inclusion of the intima.

In 1898, Gluck, who had also done excellent work in the lateral suturing of arteries, devised a method of end-to-end union by which he removed completely a small section of an artery, slipped it over one end of the artery as

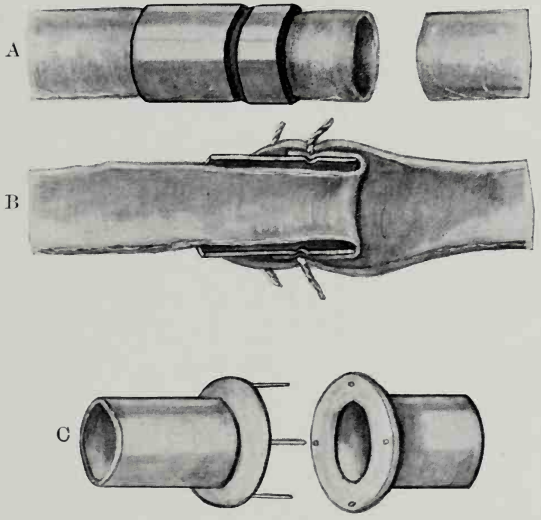


Fig. 9.—Payr's magnesium tubes and discs for uniting arteries. (A) The magnesium ring with a groove, which has been passed over the end of an artery. (B) Transverse section of the completed operation. (C) A later modification of the tube by Payr.

a ring, and after the ends were united it was drawn over the suture line to reënforce the sutures and held in this position by a few stitches. Other substances, he says, such as rings of rubber or decalcified bone may be employed.

In 1899, Dörfler published the results of his experiments and, according to Guthrie, established the main features of the methods that are now so generally used. Dörfler claimed that the essentials of successful blood-vessel suturing were fine, round needles; fine silk; and a continuous suture embracing all coats of the vessels. He

did not avoid the intima, but recommended that all coats be included in the continuous suture.

Payr, in 1900, gave a great stimulus to surgery of the blood-vessels by devising a ring of magnesium. This was a circular band shaped like a diminutive napkin ring with a groove in its outer surface (Fig. 9). This ring was slipped over the central end of an artery and the artery cuffed back and tied in the groove. The distal end of the artery was then stretched, invaginated over the cuff, and held in position by another ligature. In this manner intima was approximated to intima and the magnesium was in the course of time absorbed. The method was tried rather extensively both experimentally and clinically. According to Crile, his transfusion cannula is a modification of the ring of Payr. Payr's idea was that sutures would probably not hold and that this method would withstand arterial pressure. In 1904, Payr published an article giving his own experiments and those of others and claimed that unsuccessful results were due to the fact that his directions were not followed. He also devised two discs of magnesium with small pins on the periphery of one disc which fit into holes in the opposite disc. The end of the vessel was placed through the disc, opened widely to evert the intima, and fixed by the pins which both transfixed the walls of the vessels and clamped the opposite disc.

Bouglé, in 1901, introduced a new method of invagination, a modification of Murphy's, in which the ends were invaginated only a short distance and fastened with sutures that did not penetrate the intima of the proximal end.

In 1902, many articles appeared, among which were those of Thomaselli, Salvia and, particularly, Carrel. Salvia experimented upon dogs, donkeys, and sheep and

paid special attention to the healing of the arterial wound. He used end-to-end sutures of fine silk. In none of his cases did the lumen remain open. Thomaselli laid much stress upon approximating intima to intima. He used interrupted sutures passed through all coats with fine, curved needles and silk. In a later article he says that the method of Salomoni is the best.

Carrel published his well known method in 1902. It differs in no essential particular from the work of others, but is a combination of the best features of other work. The results obtained were much better than those secured by any one else. He used very fine, No. 16, round, straight needles, threaded with fine silk impregnated with vaseline. The adventitia is thoroughly removed and the ends of the artery washed out with salt solution, or Ringer's solution. The ends of the vessels are then united by three traction sutures inserted around the artery at equidistant points (Fig. 10). Traction on the sutures converts the circumference of the artery into a triangle, approximates the intima, and renders the suturing easy. The operator holds one traction suture, the assistant holds another, and the third is caught in a small hemostatic forceps, so as to pull the artery away from the region that is being sutured. After suturing one-third with a continuous overhand stitch the operator takes the suture held by the assistant, the assistant takes the one to which the hemostat was fastened, and the hemostat is placed upon the traction suture that the operator originally held. After the second third is finished the traction sutures are again changed, the operator taking the one held by the assistant, who makes tension on the suture that was clamped by the hemostat and the hemostat is placed on the suture just released by the operator. The last third is now completed and the current is

turned on gently. Slight pressure usually stops the oozing from the needle holes, and then the full force of the stream is released.

Very brilliant results have been secured by this technique in the hands of Carrel, Guthrie, Stephen H. Watts,

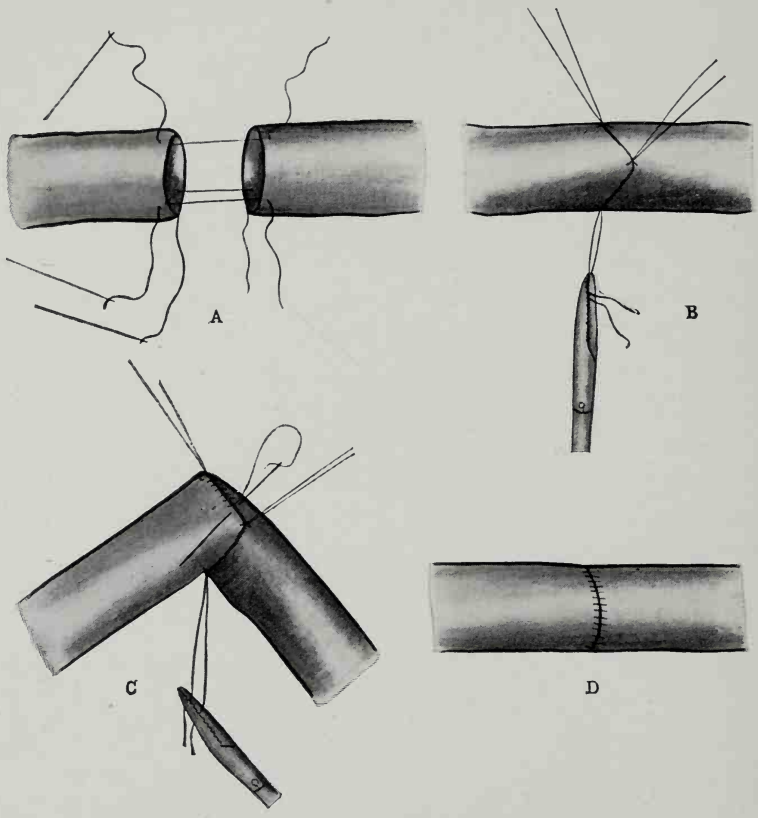


Fig. 10.—Carrel's method of end-to-end suture of arteries. (A) Three guy sutures inserted and ready to be tied. (B) The guy sutures tied and one clamped with a hemostat. (C) The suturing of one-third has almost been completed. (D) The operation completed.

and others. Watts reported, in 1907, a remarkable series of experiments on dogs in which this technique was used. Of thirteen circular sutures of the carotid, all were perfectly successful and there was not the slightest evidence

of thrombus formation. In two instances when the femoral artery was sutured, thrombosis occurred. Thirteen times the jugular vein was divided and sutured with ten successes. Microscopical examination of the arterial specimens at periods varying from twenty-eight to eighty-two days after operation showed a gradual restoration of the artery at the site of suture, all elements of the vessel wall being regenerated except the inner elastic membrane. Watts also reversed the circulation in the neck by suturing the central end of the carotid artery to the distal end of the external jugular vein. This was done four times, all being successful. Examination of the veins from one to three months after operation showed a dilatation of the vein with thickening of the walls. Microscopic examination showed changes very much like those found in arteriosclerotic arteries. He excised and reimplanted a section of the femoral artery but thrombosis occurred. Twice he transplanted a section of vein between an artery, using a section of the external jugular between the ends of the carotid in one instance and between the divided femoral in another. The carotid experiment was successful, but the transplantation into the femoral artery resulted in thrombosis.

In 1901, Clermont reported experiments on suture of the veins. He used a continuous mattress stitch of fine silk and everted the edges of the vessel. He devised a method by which the intima was united to intima by a continuous mattress suture of fine silk with a second row of overhand running sutures uniting the edges.

In 1903, Jensen published an article on the circular suturing of blood-vessels, which was very complete. He preferred silk and sutured all coats of the vessel with a continuous stitch. Hoefner, in 1903, gave a history of lateral and circular suturing of blood-vessels in ani-

mals and man, and also the results of his own experiments, using the magnesium ring of Payr.

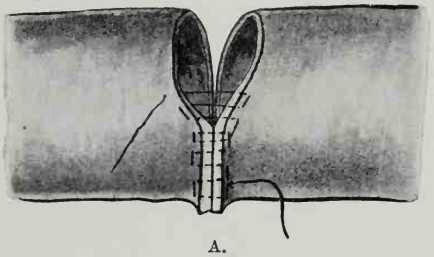
In the same year Amberg reported experimental work in which the ends of the vessel were split longitudinally so as to afford a greater surface of intima. This practically converted the vessel end into two flaps which were united by sutures. The experiments, however, were only fairly successful, as in only half of the operations was the lumen preserved.

Da Gaetano reported, in 1906, a method in which he used a small spindle-shaped glass bobbin for suturing lateral wounds of vessels or for end-to-end union. After the sutures are placed and before they are drawn tight, the bobbin is removed. He used fine silk and a round needle and did not perforate the intima. He reported satisfactory results functionally and histologically, finding new muscle and elastic tissue in the vessel scar within four months.

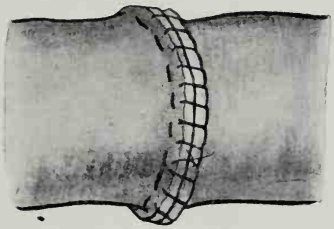
In 1906, Dorrance published an article in which he recommended that vessels be sutured by a continuous mattress stitch in which every third stitch was a back stitch so as to lock the line of sutures. After completing the suturing in this manner another row of overhand stitches was placed to reënforce the sutures after the manner of Clermont (Fig. 11). In a personal communication, Dr. Dorrance says he has dispensed with the second row of sutures as being unnecessary.

Stich, Makkas and Dowman, in 1907, reported results of experiments with a technique very similar to that of Carrel, using fine needles and silk which they immerse in liquid paraffin before using. They not only did circular suture of the arteries, but successfully transplanted a segment of a cat's aorta between the ends of a divided carotid of a dog.

E. Archibald Smith,[3] in a small monograph, reviews the literature of blood-vessel suturing and gives in detail the results of experiments with a method of his own. This consists of a "quill" suture in which chromic catgut is used for "quills." Interrupted mattress sutures are placed, everting the intima, and a strand of chromic catgut is carried under the loop of each suture, as in the old



A.



B.

Fig. 11.—Dorrance's method of suturing arteries. (A) The artery is partly sutured with a mattress stitch which drops back about every third stitch. (B) The operation completed with an overhand, reënforcing stitch. Dorrance has now abandoned the overhand stitch as being unnecessary.

quill suture. Another strand of chromic catgut is placed between the ends of each suture and the suture is tied snugly on the catgut. Less than a third of his experiments were successful.

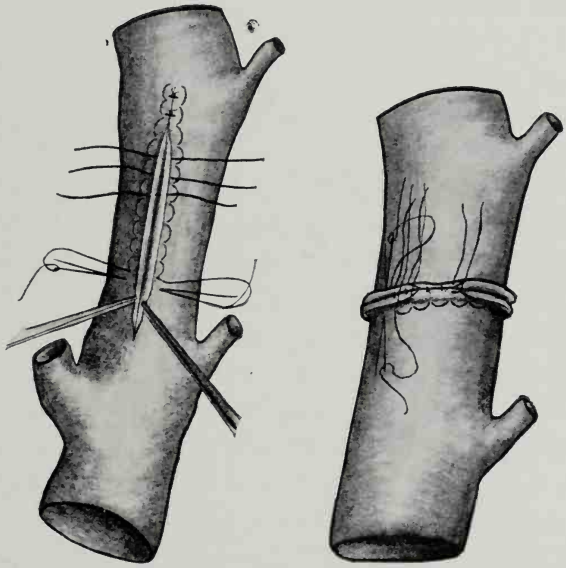
Lespinasse, Fisher and Eisenstaedt, of Chicago,[4] published excellent results of experimental work on end-to-end anastomosis of blood-vessels and on closing wounds

3 Suture of Arteries, Oxford University Press, 1909.
4 Journal A. M. A., November 19, 1910.

in arteries or veins. For lateral wounds they recommend perforated plates of magnesium. A perforated plate is placed on each side of the wound and holds the intima of the wound in contact by means of mattress sutures that are passed through the perforation and both lips of the wound. For end-to-end union, the magnesium is in the shape of discs or rings, resembling the second device of Payr, which have a number of small holes along the periphery. The end of the vessel is carried through the rings and fastened by four sutures to these holes. This flares open the end of the vessel and exposes the intima. Both ends are placed through the magnesium rings in this manner and then the rings are brought together and fastened firmly by mattress sutures passed through the opposing perforations.

The *Journal of the American Medical Association*, May 10, 1913, page 1474, says: "Lexer of Jena, showed a case of ideal operation for aneurism and transplantation of the vessels. The patient was operated on according to the rules established by Lexer in 1907. To maintain the circulation in its normal channel, the spindle-shaped aneurism beginning above Poupart's ligament and extending below the arteria profunda was removed and the defect of the vessel repaired by the introduction of a piece of saphenous vein, 18 cm. long. The wall of the artery markedly changed by arteriosclerosis allowed the thread of the running suture of Carrel to cut through. On the other hand, the continuous protruding mattress suture gave very good service; the thread not only held well but also prevented hemorrhage. The large differences in lumen of the piece of vein and that of the still enlarged artery caused little difficulty in suture. The brilliant result also shows that the piece of vein must have under-

gone an increase in size, as in experimental work. The patient was a man aged sixty-two and the case testifies beyond cavil that a transplanted vessel may remain thoroughly permeable. The arteries in the foot now pulsate as powerfully as those on the other side, but they immediately become pulseless when the femoral artery in the region of the transplanted vessel is compressed. The pa-



A. B.

Fig. 12.—(A) Mattress suture applied in a lateral wound as recommended by Bickham. (B) Mattress suture with a reënforcing stitch in a transverse wound. (Bickham.)

tient, who was operated on nine months ago, is completely free from symptoms."

Soresi, of New York, described before the Seventeenth International Medical Congress an apparatus for suturing blood-vessels which consists of a small clamp that kept the vessels approximated. Minute hooks held a turned back cuff and exposed the intima. The intima

was then approximated to intima by means of very small gold wire clamps somewhat after the fashion of Michel skin clamps.[5]

Christian and Saunderson [6] described a device for uniting blood-vessels by means of two metal rings and a holder. From the surface of each ring several very small bearded points project. The vessel is cuffed back over each ring and held by the sharp points. The two rings are fastened together with small pliable wires one-fourth of an inch long which project from the side of the ring and which are fastened together by being twisted with pliers.

John W. Price, Jr.,[7] of Louisville, has devised a method of suturing blood-vessels by means of a new instrument. "This instrument is a cannula-forceps. The cannula portion is spooled slightly at one end. The instrument is made in several sizes, so that a cannula will have a bore of 1½ mm., 2 mm., 2½ mm., 3 mm., or larger if desired. The cannula-forceps may be used in making a temporary anastomosis between two blood-vessels, as for a transfusion; for making a permanent end-to-end or end-to-side anastomosis between two vessels.

"1. The cannula is opened and then closed to include one vessel about 3 to 4 mms. from its cut end (the spooled end of the cannula is toward the cut end of the vessel); the end of the vessel is then caught by three iris hooks from within and cuffed over the spooled portion of the cannula and held.

"2. The end of the second vessel is now caught from within by three iris hooks and pulled over the everted vessel on the end of the cannula, thus the endothelial sur-

5 Journal A. M. A., September 16, 1913, page 800.
6 New Orleans Medical and Surgical Journal, November, 1913.
7 The Lancet-Clinic, January 25, 1913.

face of one vessel is brought next to the endothelial surface of the other.

"3. Two iris hooks are now passed through both vessels and held, the first set of hooks being removed.

"4. A continuous mattress suture is inserted through all the coats of both vessels at their approximated ends.

"5. Hooks are removed.

"6. The cannula is then slipped out of the cuff (away from the line of sutures), opened and removed.

"7. The Crile clamp on the vessel distal to the anastomosis is removed first, then the proximal clamp is removed, which allows the blood to flow. Additional sutures are added to control any oozing."

Muir [8] describes a method of uniting blood-vessels by means of a bone cylinder with a ridge for the retention of the ligature. The cylinders are made in different sizes. The artery is cuffed back from the cylinder and ligated; the operation is similar to the technique used in Payr's magnesium rings, or in the cannula of Crile. The bone is said to absorb, leaving no foreign body.

8 Journal-Lancet, April, 1914.

CHAPTER IV.

THE TECHNIQUE OF SUTURING BLOOD-VESSELS.

The chief difficulty to overcome in suturing blood-vessels is occlusion by clotting, and improvements in technique are intended to prevent an excessive amount of clotting. The physiology of thrombus formation is still rather vague, as it is impossible to isolate chemically some of the substances that are involved in this process, and their presence has to be taken for granted in order to support a reasonable hypothesis. There are certain general reactions, however, that all physiologists acknowledge. The direct formation of a thrombus is due to the action of fibrin ferment on fibrinogen. Fibrinogen exists normally in blood plasma. Fibrin ferment is built up from various substances and is probably formed from the action of a thromboplastic substance, called by some thrombokinase, upon thrombogen in the presence of a solution of calcium salts. Thrombokinase is not a true kinase in the sense of acting solely as a ferment, for it is used up in the process of clotting. Thrombokinase is the key to the situation, and whether it acts directly, or indirectly, as Howell claims, by combining with antithrombin in the blood and thus liberating prothrombin (thrombogen), it nevertheless is essential to clotting and to a large extent regulates the amount of thrombus formed. Thrombokinase is supposed to be present in all tissues of the body and also comes from

disorganized blood corpuscles, particularly the platelets. It seems abundant in the adventitia of blood-vessels.

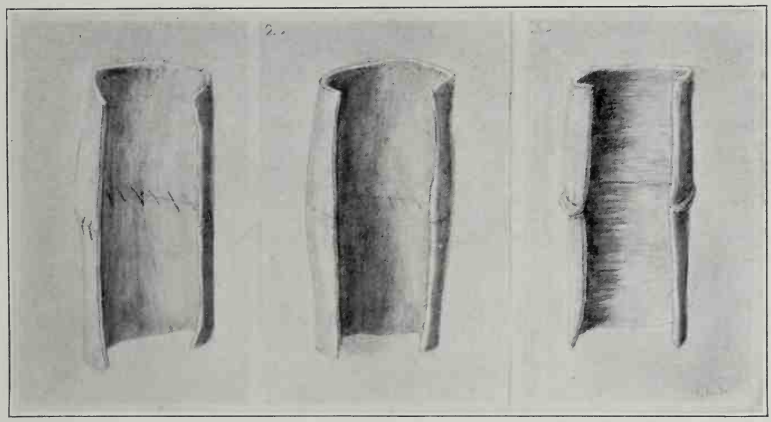
The practical bearing of these facts upon blood-vessel surgery is evident, for thrombokinase can only be liberated from injured tissue. As the amount of clotting is directly proportionate to the amount of thrombokinase, it is readily seen that any undue injury to blood-vessels by rough handling, or by drying of the endothelial cells of the intima, or by the presence of too much foreign substance in the lumen, or by chemical or bacterial injuries, will result in the liberation of so much thrombokinase that excessive thrombus is formed and the vessel is occluded. Even the most successful suturing of blood-vessels is accompanied by some clotting, but a limited amount is essential as it serves to fill the punctures from the needle holes and to bridge over the line of contact. In successful vessel suturing, however, the injury is so slight that very little thrombokinase is released and consequently only a small amount of thrombus is formed, just enough to plug the punctures made by the needle and not enough to obstruct the lumen.

We recognize, then, as the principles for successful blood-vessel suturing that a continuous surface of vascular endothelium must line the lumen and that as little injury as possible must be done this endothelium. The importance of presenting to the lumen of the vessel a continuous surface of vascular endothelium, is appreciated when we recall what has been learned in a somewhat coarser fashion by intestinal suturing. Here it is a well recognized principle, as it is in blood-vessel suturing, that the endothelial surfaces must be approximated accurately. In the case of the bowel, the endothelium is on the *outside* and it is necessary to turn *in* a small flange or shelf to secure accurate apposition of the peritoneal endo-

thelium. In blood-vessels the endothelium is on the *inside* and it is essential to turn *out* a flange in order to approximate the endothelial lining of the blood-vessel. The usual method of suturing blood-vessels consists in first placing three guy sutures and then whipping the edges of the vessel together by an overhand stitch. This necessarily cannot approximate the endothelial surface on the inside as accurately as would a mattress stitch that turns *out* a flange and compels the apposition of the intima. No one would think of suturing a bowel in a similar manner and claim that the peritoneum could be accurately brought together by merely whipping over the margins of the bowel wound as in suturing skin. If this cannot be done in intestinal surgery, the same thing holds equally in blood-vessel surgery.

The presence of foreign substances in the lumen of a blood-vessel promotes clotting. Some substances favor clotting more than others. A coating of vaseline or paraffin retards clotting. Other things being equal, however, the larger the amount of foreign substance or raw surface in the blood vessel, the greater the likelihood of extensive clotting. A mattress suture which turns *out* a flange not only approximates the intima more accurately but leaves almost no thread exposed in the lumen; whereas the continuous overhand stitch leaves a considerable amount of thread in the lumen. This is readily seen from the accompanying cut (Fig. 13a) which is reproduced from Guthrie's work on blood-vessel surgery and shows the inside of the vessel soon after being sutured by the usual method. The mattress suture which is parallel to the wound also secures a better hold upon the tissues than the overhand stitch which is at right angles to the wound and the mattress stitch is, consequently, less liable to cut (Fig. 13c). This is due to the fact that in

the mattress suture the tension is more equally distributed along the whole loop of the stitch, whereas in the overhand stitch the tension is concentrated at one point, that is, at the end of the suture farthest from the wound. This fact has been brought out by Lexer in a case that has already been referred to (page 42). Lexer excised



A. B. C.

Fig. 13.—(A) This drawing, reproduced from Guthrie, shows the appearance of the lumen of a blood-vessel immediately after it is sutured by the method of Carrel. Note the large amount of thread exposed in the lumen.

(B) This drawing, also from Guthrie, shows the appearance of the lumen of a blood-vessel several weeks after successful suturing. The stitches have been covered by endothelium which is still partly transparent. The older the specimen, the thicker and more opaque becomes the covering over the sutures until, after several months, the stitches are completely hidden from view. This is true of any method of suturing whether the mattress or overhand stitch is used. It is the first day or two after the suturing (before the stitches are covered) that the amount of thread in the lumen is important. Sutures seem to work away from endothelial surfaces toward the lumen in the intestine and toward the surface in blood-vessels.

(C) This drawing shows the eversion of the intima caused by the double mattress stitch and the consequent absence of any raw surface left in the lumen of the vessel. Note the very small amount of thread left exposed to the blood current as compared with "A." Note also the strong grip that the loop of the mattress stitch has on the tissue.

an aneurism and sutured a piece of the saphenous vein into the defect. "The wall of the artery markedly changed by arteriosclerosis allowed the threads of the running suture of Carrel to cut through. On the other hand, the continuous protruding mattress suture gave very good service; the thread not only held well but also prevented hemorrhage."

Asepsis in blood-vessel suturing should be as nearly perfect as possible, just as it should be in abdominal surgery, brain surgery, or bone surgery. If the tissues around the blood-vessels are infected no suturing can be expected to be satisfactory. Yet even in the presence of infection it is not invariably a failure, as the author has one successfully sutured femoral artery in a dog in which the tissues around the vessel suppurated for several weeks. As a rule, however, infection will result in failure and the proper aseptic technique should be insisted upon. Particularly should dust be avoided. The operator should wear a mask over his mouth and the floor of the operating room should preferably be moist. In laboratory work the floor should be flushed with water an hour or two before operating. The manner of handling tissues is most important, for gentleness is an absolute essential. No matter how careful the aseptic technique, good results cannot be secured by one who uses the same methods of handling tissue in blood-vessel surgery as would be adopted in bone surgery. The vascular endothelium should not be permitted to dry and should not be touched with any instrument.

As for instruments, the author uses No. 16 straight needles threaded with 00000 twisted black silk. They are threaded with silk about fourteen inches long and a single knot is tied on the eye of the needle to prevent it becoming unthreaded. The short end should be cut within half an inch of the needle to avoid unnecessary loose ends dangling about. Five of these threaded needles are run through a piece of gauze of double thickness about two inches wide and as long as the thread. This gauze is then placed in a small can or ointment jar that is one-third full of white vaseline. More vaseline is put over the gauze and the jar is closed and sterilized.

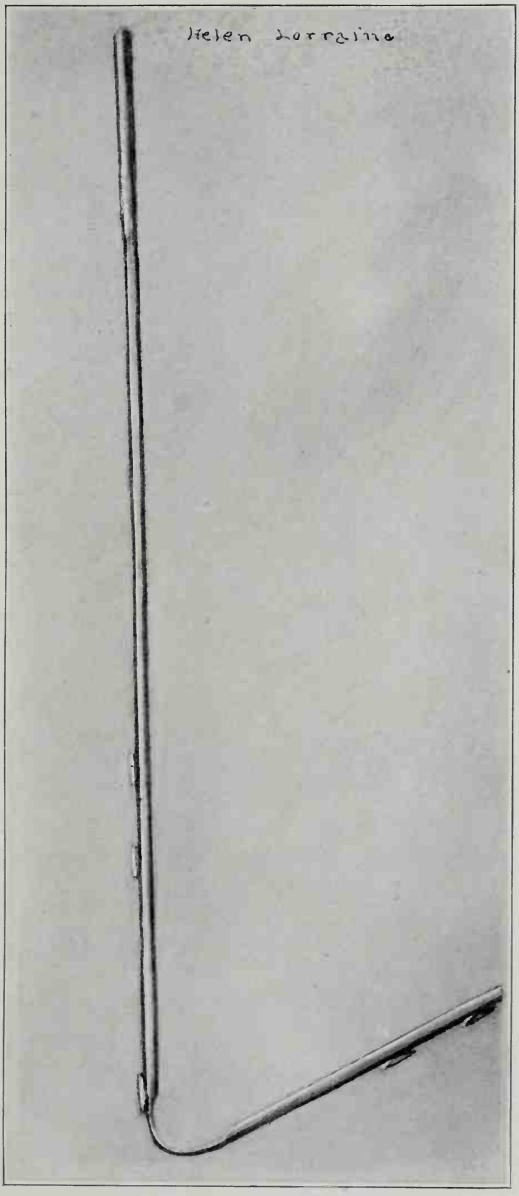


Fig. 14.—Arterial suture staff.

The needles are not removed until they are to be used, when they are taken from the gauze and the gauze, which is thoroughly impregnated with vaseline, is laid beneath the artery to protect it from the surrounding tissue. To place the cobbler's stitch satisfactorily, it is necessary to have an instrument called "an arterial suture staff" which the author has devised in an effort to simplify the technique. This instrument (Fig. 14) consists of a small steel shaft which curves at one extremity into a shorter shaft. The long shaft, or handle, is six inches long, and the short shaft is one and three-quarters inches long and is placed at an angle of about sixty degrees to the long shaft. The curved portion is flattened to form a spring. There are five buttons; one on the main shaft as close as possible to the curved spring, one at the extremity of the short shaft, one just below this, and two on the main shaft at points about opposite the buttons on the short shaft. These buttons hug the instrument closely and are so constructed that the guy sutures are securely held by simply wrapping them twice around the buttons.[1] In order to occlude the vessel, either a rubber covered Crile clamp is used, or the ordinary serrefine, or bulldog clamp, uncovered, which has a spring so weakened that the clamp can grasp the skin of the forearm without pain. The inside of the vessel should never be caught with forceps, though sometimes it is necessary to grasp the outside. For this purpose the ordinary thumb forceps called "frog forceps" by the instrument dealers and sold for biological dissection are excellent. Several mosquito hemostatic forceps are needed (Fig. 15). Aside from these special instruments, the usual instruments may be employed. The knife and scissors should be sharp.

1 The arterial suture staff is made by The Kny-Scheerer Company, of New York, and by Sharp & Smith, of Chicago. Powers & Anderson, Inc., Richmond, Virginia, keep in stock the staff and the set of instruments and sutures used in vessel suturing.

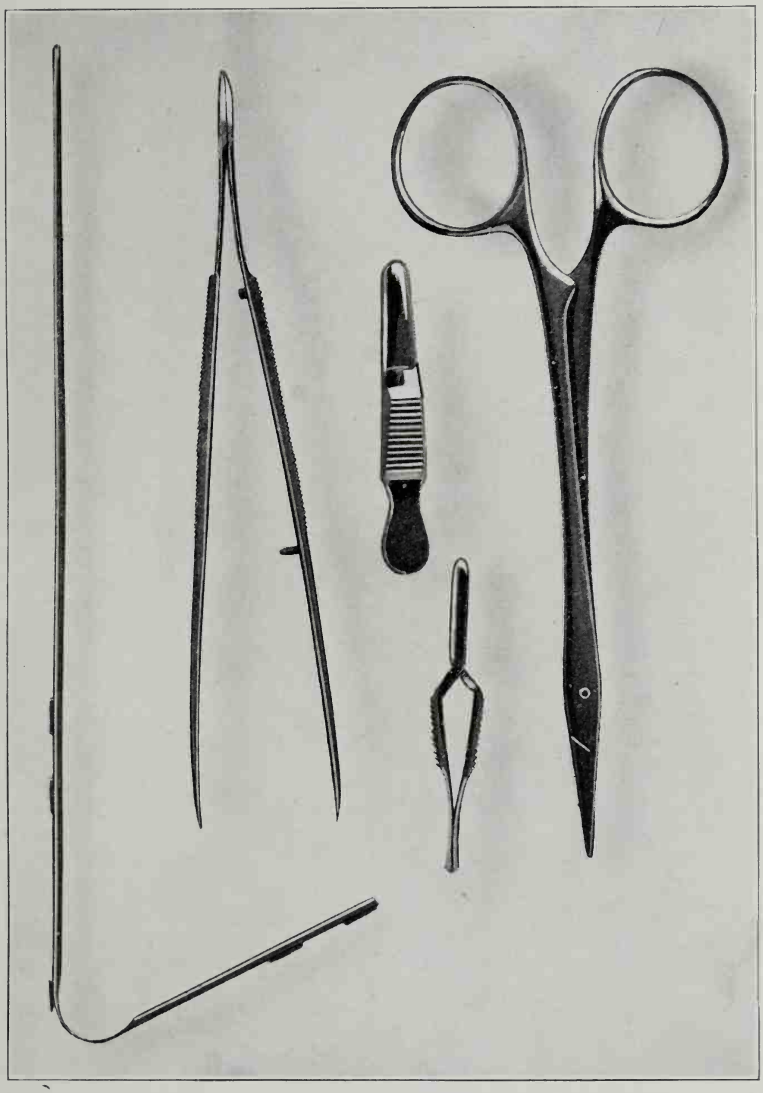


Fig. 15.—Special instruments used in end-to-end suturing of blood-vessels. On the left is the arterial suture staff and next to it a small thumb forceps called "frog forceps." On the right is a "mosquito" hemostatic forceps and next to it two serrefines, or "bulldog" forceps.

The vessel is exposed, keeping the tissues as dry as possible. A serrefine is placed on the portion of the vessel nearest the heart, and the vessel is then gently grasped between the thumb and finger and stripped of blood to the other angle of the wound, where another

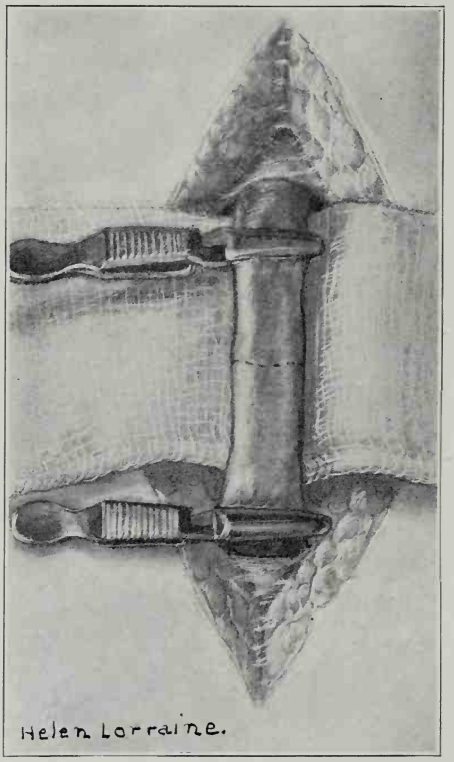


Fig. 16.—The artery is exposed, blood stripped from it and serrefine clamps are placed. Gauze soaked in vaseline is under the artery. The dotted line shows the proposed incision.

serrefine is placed. This leaves the artery dry and flat like a ribbon. The vaselinized gauze from which the needles have been removed is now placed beneath the vessel (Fig. 16), after stopping all bleeding in the wound, and the artery is divided with one stroke of sharp scissors. The fingers are wiped free of blood and moist-

ure on a dry towel and the left finger and thumb grasp one of the ends of the artery rather firmly and pull the adventitia over its cut end. The adventitia is cut off on a level with the rest of the artery (Fig. 17). It then retracts, leaving the middle and inner coats exposed.

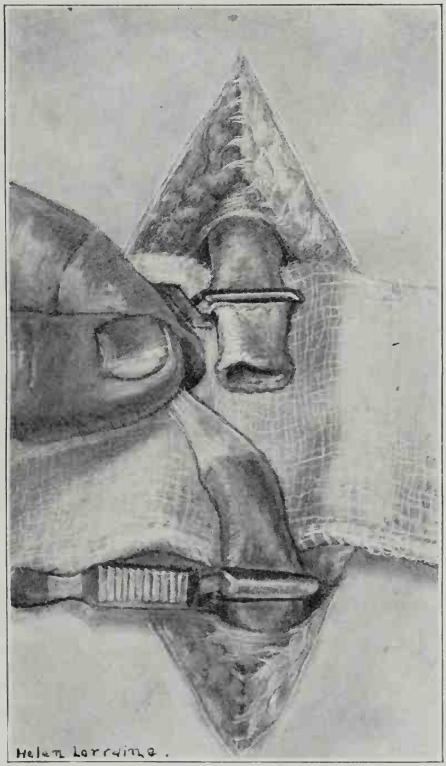


Fig. 17.—The artery is severed by sharp scissors. The adventitia curls over the ends of the artery. Illustration shows the finger and thumb grasping the adventitia from one end of the artery and pulling it up. This redundant adventitia is cut away and the rest then retracts, leaving a clear-cut margin of the artery. Both ends are treated in a similar manner.

Any remaining clots in the vessel are stripped out with the thumb and finger and the end is held firmly between the thumb and finger of the left hand and sponged with dry gauze (Fig. 18). As the artery is collapsed and its end held between the finger and thumb the gauze cannot

touch the intima but merely wipes the wounded portion and so removes any excess of thrombokinase. The tip of a finger of the right hand is then dipped in white vaseline and the end of the artery is smeared over with vaseline

Fig. 18.—The thumb and finger of the left hand grasp the end of the artery after the adventitia has been removed and a finger of the right hand anoints the collapsed end with vaseline.

immediately after being sponged. This serves to keep back any further juices from the severed artery and also prevents drying of the intima. The other end of the vessel is treated in the same manner.

All of these manipulations are done rapidly for it is essential to complete the suturing as quickly as possible after the intima has been exposed. One of the sutures which has been prepared as directed is inserted from without inward at one end of the artery and from within outward at the other end. An artery is quite tough and a small bite will be sufficient. If too much is taken, the intima cannot be properly everted. The first loop of a knot is tied, bringing the ends of the vessel together. The second loop of the knot is tied while holding the ends

of the suture taut, running the knot down in this manner to prevent the first loop from slipping. After tying this suture, the arterial suture staff is placed under the artery with the short shaft pointing toward the operator. The

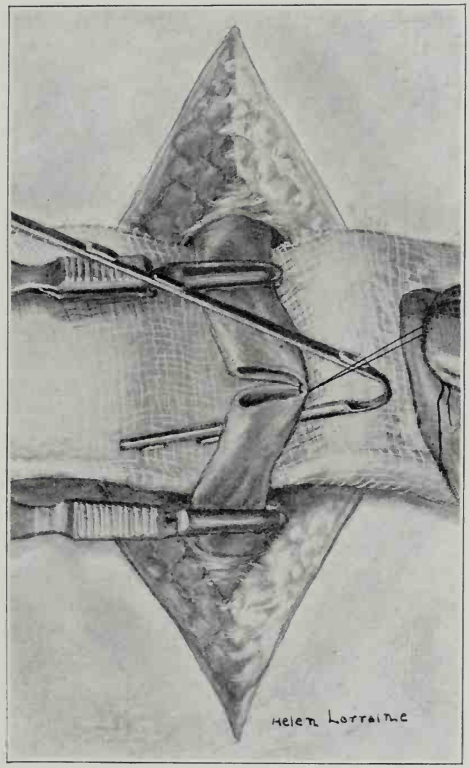


Fig. 19.—A suture has been inserted going from without inward at one end of the artery and from within outward at the other end. It is tied and the arterial suture staff is placed under the artery with the short shaft pointing toward the operator. This guy suture is then wrapped two or three times around the lowest button on the long shaft of the staff and is cut short. Its length from the button to the artery should be about one-half an inch.

guy suture is fastened by wrapping it two or three times around the lowest button on the long shaft, and is cut short (Fig. 19). The length of the suture from the button to the vessel should be about half an inch. The second suture is placed about one-third of the way around

the circumference of the vessel and should be on the side away from the operator. The suture staff can be laid flat so that the short shaft is not in the way and the vessel ends can rest upon the long shaft, thus making it

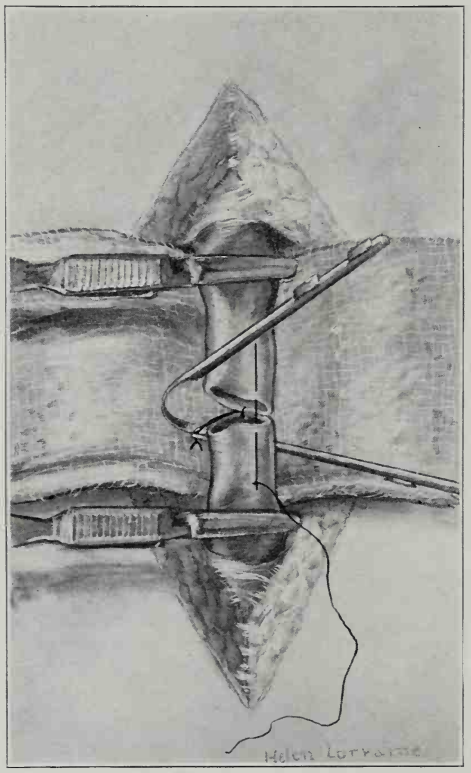


Fig. 20.—The handle of the arterial suture staff is depressed away from the operator and the short shaft may be turned flat and caught so as to manipulate the ends of the artery into a more convenient position for inserting the second suture. The second suture is inserted, tied, and wrapped around one of the upper buttons on the long shaft.

easier to insert the second suture (Fig. 20). The second suture is inserted and tied in the same manner as the first and is wrapped around one of the upper buttons on the long shaft. The threaded end is left long for future suturing but the other end is cut close to the button. As

two guy sutures are now fixed to the long shaft, the third one is easily inserted by raising up the long shaft when the point of insertion of the third suture is indicated by the retraction of the margins of the artery. The needle

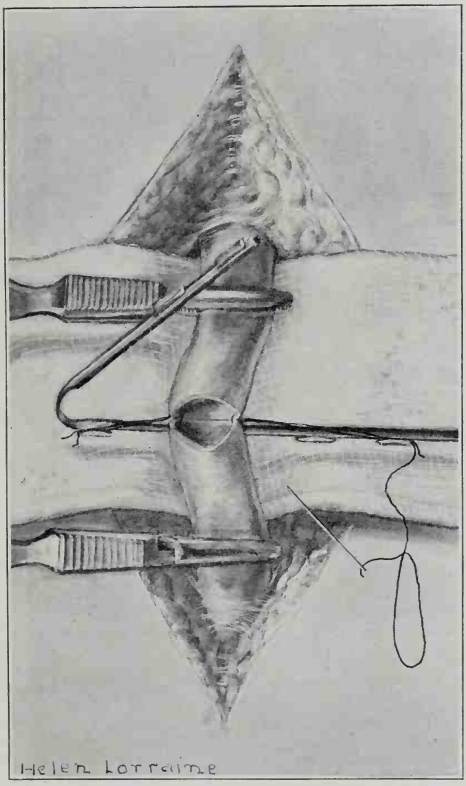


Fig. 21.—The threaded end of this guy suture is left long for future suturing. The unthreaded end is cut short. The vessel can now be lifted on the staff when the apex of the retracted margins will indicate the point for insertion of the third guy suture. This staff makes the insertion of the second and, particularly, the third guy suture much easier.

is inserted at the apex of the retracted margin (Fig. 21). After this suture is tied, the short shaft is slightly compressed toward the long shaft and this guy suture is wrapped around one of the buttons on the end of the short shaft (Fig. 22). The threaded end is left long and

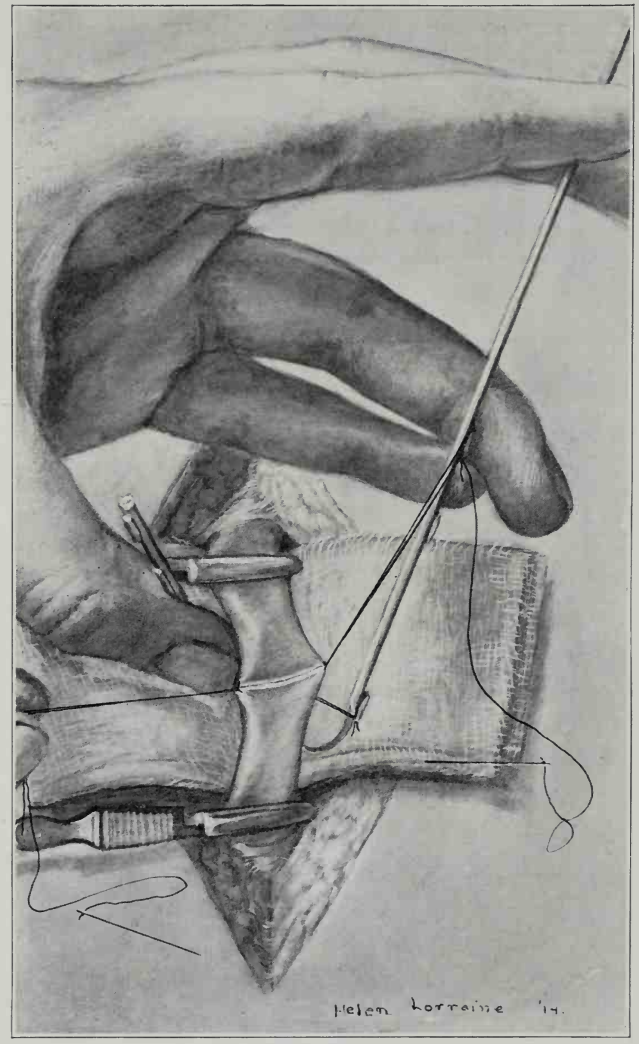


Fig. 22.—After insertion of the third guy suture, it is tied in the usual manner, all sutures being about equidistant. The suture staff is then grasped by the handle in the manner indicated in this drawing, and the short shaft is slightly compressed toward the long shaft. While held in this position, the third guy suture is wrapped around one of the buttons on the end of the short shaft.

the unthreaded end is cut close, as in the second suture. It is important to have no unnecessary ends hanging loose. The short shaft is released and the spring makes tension on the margins of the artery, converting its cir-

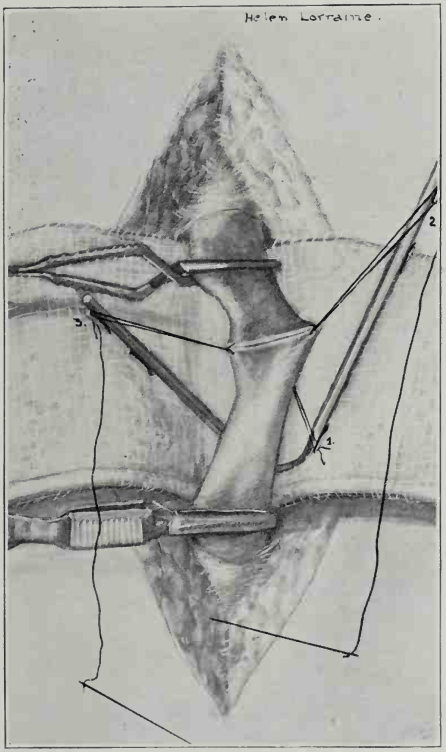


Fig. 23.—When the tension is relaxed by removal of the hand, the spring makes traction on all three guy sutures, converting the circumference of the vessel into a triangle and everting the intima. The suture staff should have an abundantly wide angle, the short shaft being at least 60 degrees to the long shaft. With a narrow angle there is not enough tension and there is also not enough room for suturing.

cumference into a triangle, and everting the intima (Fig. 23).

The three guy sutures are inserted in the same way when an artery is joined to a vein of much larger caliber as when a divided artery is united. Sometimes it is a

little more difficult when a small artery is sutured to a large vein, but after the guy sutures are once inserted, the rest of the procedure is identical whether vessels of equal or unequal caliber are to be united.

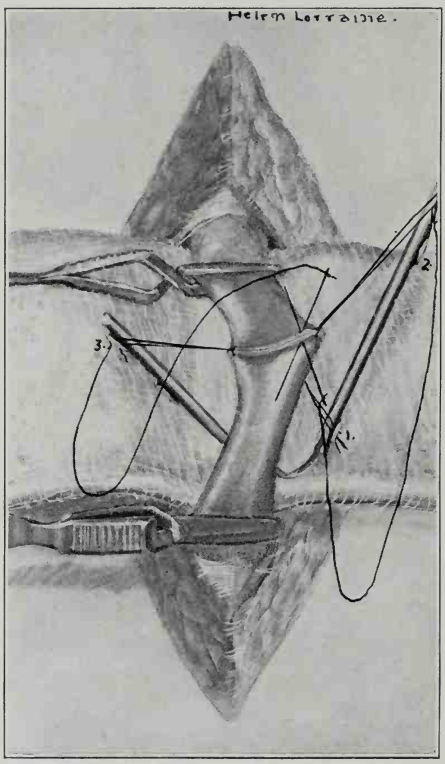


Fig. 24.—The handle of the staff is upright and the whole instrument is lifted up so as to increase the eversion of the intima. The continuous, double mattress, or cobbler's stitch, is begun by using the threaded ends of the last two guy sutures. The needles are thrust through the margins of the artery near the second guy suture and should be inserted at right angles to each other so they can be handled better. The suturing in this third is done toward the operator, that is, from the second to the third guy suture.

We now have two needles from the two guy sutures last inserted. A needle is taken in each hand and thrust through both margins of the artery in the region where the second suture was tied. The threaded needle from the third guy suture at the end of the short shaft will, of

course, carry a little loop of thread which is of no consequence. The instrument is lifted up so as to elevate the upper third of the wound and increase the eversion. The suture is then applied in the manner of the double mattress, or cobbler's stitch, going from the second guy suture to the third (Fig. 24). At the angles particular

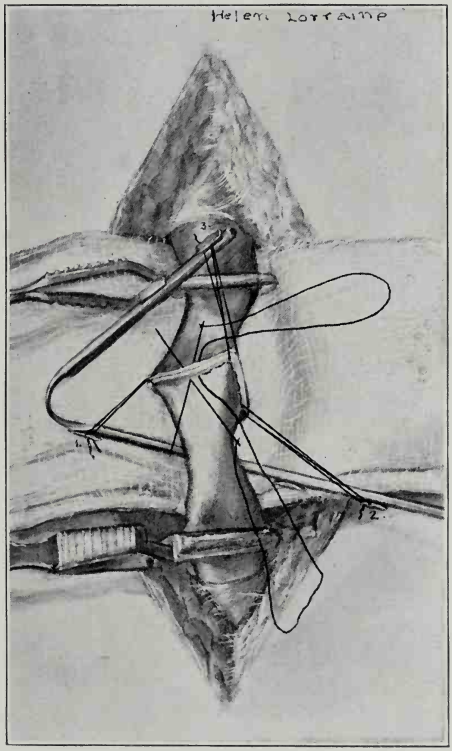


Fig. 25.—The handle of the staff is depressed until it is horizontal and points away from the operator. Then the whole instrument is shoved *toward* the operator so as to increase the eversion in the second third. The suturing is continued as a cobbler's stitch.

care should be taken to go beneath the insertion of the guy sutures; otherwise, the tension of the guy sutures may produce a wound in the endothelium which would be exposed to the lumen of the vessel. After the first third

has been sutured, the handle of the instrument is depressed away from the operator and the instrument *shoved toward the operator* so as to increase the eversion of this third of the margin of the vessel (Fig. 25). The suturing is continued as a cobbler's stitch. When the

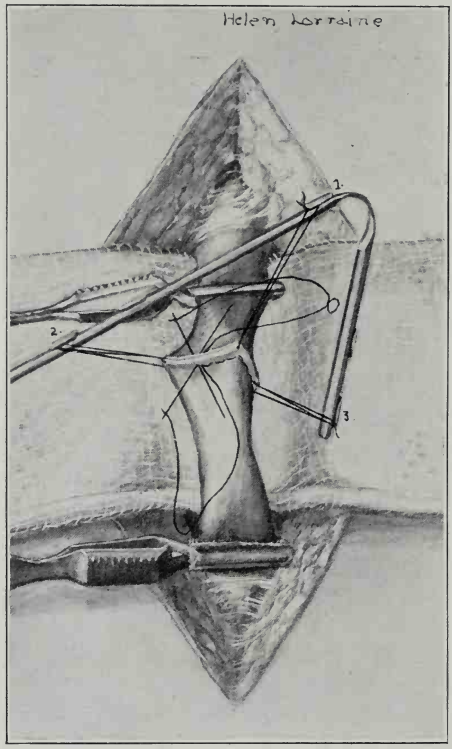


Fig. 26.—The handle of the staff is then brought over to a horizontal position pointing toward the operator. The instrument is *lifted up* so as to increase the eversion of the last third. The suturing is continued toward the second guy suture.

second third is finished, the instrument is brought to its original position and each needle carried under the vessel so as to be ready for suturing the last third. The handle is then depressed *toward* the operator and held in such a manner as to lift up the last third and so increase its eversion (Fig. 26). The suturing is continued through

the last third and when this is finished the instrument is brought back to its original position and the suturing carried about two stitches beyond the point of commencement, where the threads are tied to each other. Each stitch must be drawn snugly when it is placed, else the intima will not be securely approximated and there will be leakage. In the carotid of a dog of medium size about five stitches are put in each third of the artery.

Sometimes, particularly in old dogs, retraction of the ends of the artery is marked and the sutures cannot be properly placed as they will tend to cut out or break under the tension. If the adventitia of the vessel is grasped with curved mosquito forceps about one and one-half inches from the severed ends, the two ends of the vessel can be shoved together by an assistant without tension on the sutures and without his hands being in the way of the operator. This is better than trying to approximate the ends by the serrefine clamps which may either come off or loosen and flood the vessel with blood. After the suturing has been completed, the short shaft is slightly compressed toward the main shaft so as to relax the tension on the guy sutures and the *distal* clamp on the vessel is slowly released (Fig. 27). If there is marked spurting at any point, an extra suture should be placed there. With a little experience spurting rarely occurs, though there is usually oozing of a few drops of blood. The guy sutures are then cut and the instrument is removed. The sutured vessel is very gently compressed with dry gauze and the distal clamp is entirely removed. After about a minute the proximal clamp is slowly removed. In this time the needle holes should be plugged with fibrin and there should be no leakage. The vessel must not be returned to its bed until leakage has ceased. The whole procedure of suturing the vessel,

Fig. 27.—The handle of the instrument is brought to a vertical position and, the suturing having been carried about two stitches beyond its point of commencement, the threads are tied to each other. The distal clamp is slowly removed and the staff somewhat compressed so as to relax the guy sutures and demonstrate if there is any spurting point along the suture line. After a minute, the other clamp is removed, and if no spurting exists the guy sutures are cut. If any spurting does occur, the clamps can be reapplied and an extra stitch taken at the spurting point. With a little practice, however, this is rarely necessary.

from the insertion of the guy sutures to the last stitch, can easily be done in from ten to fifteen minutes and often in less time. Any competent surgeon who tries this technique experimentally a few times can master it.

This method has been mentioned in several journals.[2] The arterial suture staff has not been altered and the general principle of approximating the intima has always been adhered to. However, several details of applying this principle have been changed, and it is the author's opinion that these changes add to the value of the technique. The staff holds the vessels so that the edges are everted and each stitch is inserted under the same tension from the first to the last. It greatly facilitates the suturing and makes possible the carrying out of the principles that have already been noted. The arterial suture staff not only renders easier the placing of the last two guy sutures, but holds all of them in proper position and under uniform tension throughout the operation. By means of this instrument the tension is kept even at all points along the arterial wound. There are no long ends of sutures to become entangled and there is no necessity for several changes with the alternate increase and relaxation of tension when the sutures are handled in the ordinary way, which necessarily interferes with the regularity and accuracy of the suturing. Any one can hold it; an assistant trained in blood-vessel surgery is not needed.

The changes are as follows:

1. A double mattress or cobbler's stitch is now used instead of the single mattress stitch as originally advised. It was found that when the single mattress stitch was used there were points between sutures with but

2 Annals of Surgery, February, 1912; Journal A. M. A., July 6, 1912, and December 14, 1912; Surgery, Gynecology & Obstetrics, May, 1914.

little compression and no raw surface. This sometimes made a small amount of leakage that was difficult to control; also a little diverticulum would be formed that was a weak spot and would occasionally result in secondary hemorrhage. The double mattress stitch does away with these objections and approximates the intima firmly as by a fine clamp around the entire margins of the vessel; at the same time it exposes no more thread in the lumen, than is exposed by the single mattress stitch. The use of this stitch can be readily acquired by any one who tries it. It has been most successfully used in intestinal suturing by Crile, and is much more needed in vessel suturing, as there is more pressure in a blood-vessel than in the bowel. As the operator must use both hands while inserting the cobbler's stitch, it would be difficult to place this stitch evenly and satisfactorily without the suture staff, as the three guy sutures would have to be manipulated by hand.

2. No salt solution is now used to wash out the vessels. It has been the object of this technique to eliminate as far as possible every procedure that is not essential to success. Washing out the ends of the vessel with salt solution not only adds somewhat to the trauma of the endothelium, makes a sloppy wound, and prolongs the procedure, but according to Guthrie, rather tends to increase clotting than diminish it.

3. In order to strengthen the second and third guy sutures both ends of these sutures are now wrapped around the buttons, instead of merely using the unthreaded ends, as was formerly advised. Instead of first inserting the guy sutures and then placing them on the suture staff, it is better to fix them on the staff as they are inserted. This not only relieves the necessity of handling the sutures twice, when once will do, but it is

much easier to place the second and third sutures when the first has been fastened to the staff, as the staff can then be so maniuplated as to bring the margins of the vessel wound into a more advantageous position for suturing.

The technique as described is quite simple and the services of a trained assistant are not needed. It can be acquired as readily as the technique of suturing intestines. Dr. E. L. Caudill, an intern at St. Elizabeth's Hospital, Richmond, Va., who had never done an operation, but merely assisted in a few surgical operations on patients and in suturing arteries on animals, divided the carotid artery of a dog and united it by this technique three times. This was done without any assistance except that of a medical student and of the orderly who gave the anesthetic. No one else was present. Of the three operations two of them were successful and showed a lumen free from any thrombus two weeks and six weeks, respectively, after the operation. The third operation was unsuccessful, as the artery was occluded by thrombus. He undertook experimental work on suturing intestines and according to his own expression found it much more difficult to unite a divided bowel successfully than to unite a divided artery. There seems no reason why surgeons who are likely to need the technique of blood-vessel surgery should not easily acquire it.

The transplantation of a segment of a vein, or of an artery, or of a rubber tube involves the same technique as suturing a divided vessel. It is best, however, to have two arterial suture staffs instead of one. Three guy sutures should be placed at one end but only the first two fastened to the staff. Then the other end of the transplant can be sutured with another staff in the usual way. After this is completed, the first staff is taken up,

the third guy suture fastened to the end of the short shaft, and the suturing completed. In this way there is no inconvenience from the presence of two suture staffs in the wound at the same time, but if all three guy sutures were placed in position on the first suture staff, the short end of the staff would project so as to interfere with the suturing at the second suture staff. A transplant can be taken either from a vein or artery, or a piece of rubber tubing can be used. For practical purposes the vein is best. In experimental work the external jugular of the dog is the most suitable vein to transplant. It is readily accessible, is large, and has but few branches. Transplantation after resection of the carotid is more likely to be successful in experimental work than transplanting in the femoral because the neck is much less likely to be infected than the leg. This has been pointed out by Watts.

Some attention must be given to securing a section of the vein that is to be transplanted. The saphenous is the best vein to use as a transplant in man. The vein must be exposed and handled gently. A much longer portion should be taken than is supposed to be necessary for it contracts greatly after being removed and it is a simple matter to cut off any excess if it is too long. The vein should be dissected free while it is distended with blood and the adventitia of that portion of the vein which is to be cut should be very carefully removed while the vein is distended, otherwise it retracts within the adventitia and as the vein is exceedingly thin, cleaning away the adventitia is difficult after the collapsed segment has been removed. When the adventitia has been sufficiently removed, any pressure that caused the vein to become distended is released and a ligature placed on the distal portion of the vein. The blood is

then gently stripped out of the vein and another ligature placed at the proximal end. The vein is cut across with sharp scissors, at one stroke if possible. After the blood has been stripped from the vein it should be entirely collapsed and like a ribbon. When the end is cut it is sponged with dry gauze and thoroughly anointed with white vaseline, as mentioned in the technique of vessel suturing (page 56), only more vaseline should be used here. The other end is then divided and treated in a similar manner. The vein is placed on a sterile towel and should be used as quickly as possible. The vein should not be removed until the other dissection has been completed, so that suturing of the vein into the defect can be proceeded with at once. There is no occasion for washing out the segment of vein or for keeping it in salt solution. If for any reason it is necessary to keep the segment awhile, it may be placed on a towel or piece of gauze that has been wrung out of salt solution, and another piece of gauze similarly wrung out is placed over it. It is not necessary for the salt solution to be warm. It has been proven that cold tends to retard thrombus formation and segments of vessels can be kept in cold storage for weeks and then sutured successfully.

The author has used experimentally rubber tubing of various kinds to replace an arterial segment (Fig. 28). This in most instances becomes readily covered with tissue that resembles the adventitia of a blood-vessel. It is well known that rubber when properly prepared is very slightly irritating to the tissues. Dentists make frequent use of it. If, then, adventitia can be thrown around the rubber tube as an encapsulation, it would probably support the blood current after the rubber had degenerated. The high reproductive power of vascular

endothelium is frequently observed in the rapid lining of aneurisms that have suddenly enlarged, and it seems possible that this endothelium might cover the inner surface of the rubber tubing. In this way a strong adventitia and an intima may, possibly, be secured. Experimentally, however, the author has not been able to obtain such a result. Though the tube is often *encapsul-*

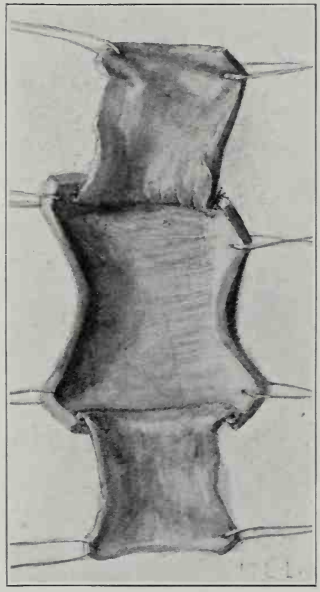


Fig. 28.—A piece of rubber tube sutured in between the cut ends of an artery. Note the complete absence of any sharp margin of the tube and the absence of thread in the lumen. This cannot be done by the regular overhand suture.

ated with a membrane that resembles adventitia, its internal surface has so far been invariably blocked, sooner or later, by thrombus. Tubes have varied from thick, black rubber to very thin rubber, and have been coated with vaseline or paraffin. While it would be impossible to suture tubes, especially thick tubes, by the overhand stitch, and at the same time make an accurate approximation and avoid sharp edges of the tube pointing

inward, by using a mattress suture and preferably the double mattress with the staff that has been described, the sharp edges are everted. While so far the author has not met with success in having the rubber tube remain permanently patent, the thrombus formation in some instances at least must have been slow. Clinically, it is just as satisfactory to have a slowly forming thrombus in a tube of this character, which would

Fig. 29.

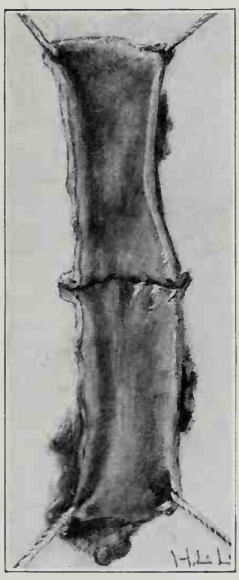


Fig. 30.

Fig. 29.—An iliac artery of a dog which was removed a few minutes after suturing after the blood had been turned on and no leakage appeared. Note the eversion of the intima constituting a flange without diminution of the caliber.

Fig. 30.—The lumen of the carotid artery of a medium sized dog. The blood had been allowed to flow for a few minutes and there was no leakage. Note the absence of thread in the lumen.

permit collateral circulation to form, as it is to have the tube remain permanently open (Fig. 28).

The possibilities of using a rubber tube in this manner clinically have been suggested by an experiment in which the author resected a portion of the abdominal aorta of a dog and transplanted a piece of rubber tube

to fill the defect. The portion resected was below the renal arteries. The tube was a soft, black rubber tube coated with paraffin. It was much thicker than was

Fig. 31.—A segment of an external jugular vein which was sutured in the place of a resected portion of the right carotid of a large dog. Note the valves about the middle of the specimen in one of which is a small clot. The specimen was dilated at this point, probably from the force of the blood stream in overcoming the valves. Otherwise the intima is perfectly smooth and the sutures are mostly buried from view. The specimen was removed 63 days after operation.

really necessary, and the suturing was more difficult than if a thinner tube had been used. The dog was a medium sized female mongrel. There was very little

leakage, which was easily controlled by pressure. The peritoneal tissues were sutured over the tube and the abdominal wound was closed in layers. The dog made

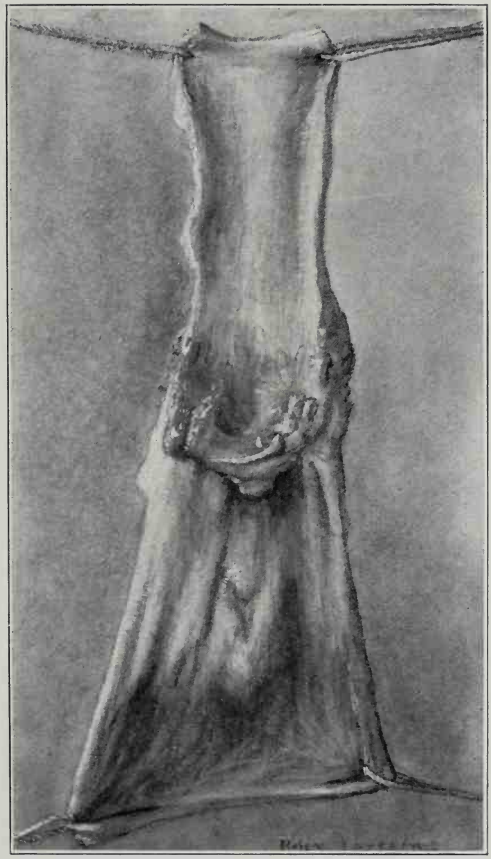


Fig. 32.—Specimen of reversal of circulation in the neck. The proximal end of the carotid was sutured to the distal end of the external jugular vein in a medium sized dog. This specimen was removed after thirty-nine days. The sutures are distinctly buried, though the endothelium over them is still transparent at places. The line of suturing is smooth. A short distance from the line of sutures are the crumpled-up valves which were forced and broken down by the blood stream.

a satisfactory recovery, there being no paralysis of the hind legs. As function had apparently not been interfered with it was hoped that the tube had remained

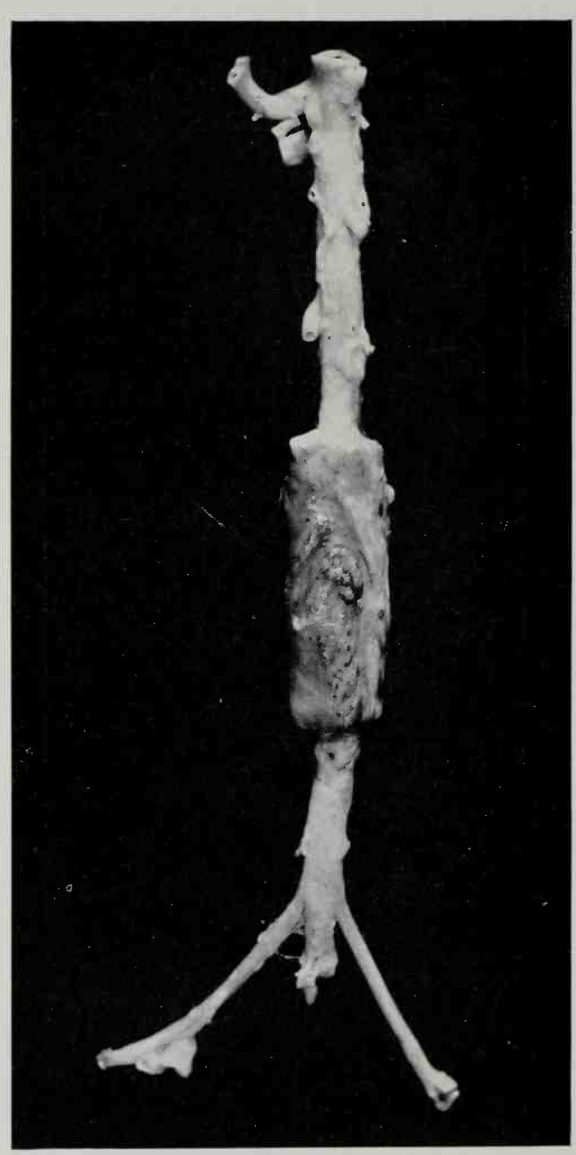


Fig. 33.—Photograph of a specimen in which a rubber tube was sutured into the defect caused by excision of a part of the abdominal aorta. The tube was removed after six months. The suturing was done according to the method recommended. The tube was completely encapsulated, though it was occluded.

patent. Six months after this operation, the dog appeared in perfect health. The dog was then photographed, killed with chloroform, and the specimen removed. The lumen of the tube, however, was occluded with thrombus. There was no dilatation nor any evi-

Fig. 34.—Photograph of a dog in which a portion of the abdominal aorta was resected and a rubber tube sutured in to fill the defect. The dog made a perfect recovery. The photograph was taken six months after operation. The dog was then killed and the specimen removed. The tube was completely encapsulated but was occluded. The occlusion was evidently gradual, as there were no bad symptoms and no paralysis of the legs. Gradual occlusion which permits time for collateral circulation is clinically as satisfactory as if the tube had remained patent.

dence of formation of an aneurism. The outline of the tube is plainly seen in the photograph. The external caliber of the tube was considerably larger than the external caliber of the artery. (Figs. 33 and 34.)

Ligation of the aorta in man has been universally fatal. This experiment suggests a possible substitute for ligation.

Lateral and Incomplete Transverse Wounds of Blood-Vessels.

The preliminary steps in suturing lateral or transverse wounds of blood-vessels are the same as those outlined under the description of end-to-end suturing. The wound should be a clean cut. If ragged or bruised, the margins are trimmed with sharp scissors. If a transverse wound involves more than half the circumference of a vessel, the vessel should be completely divided and then united by the end-to-end method. If the whole circumference is contused or lacerated, the damaged section must be excised, and if the ends of the vessel cannot be sutured together without too much tension, a transplant of vein may be used (page 69).

The method to be adopted in suturing these wounds depends partly upon the nature of the wound, but largely upon the accessibility of the blood-vessel. When possible, the vessel should be freely exposed by a long incision. The adventitia along the edges of the wound should be trimmed away with sharp scissors, blood-clots removed, and the edges of the wound and the intima anointed with white vaseline. If the wound is parallel with the vessel, it may be grasped with the forceps used for lateral anastomosis of blood-vessels (described on page 84) and sutured with a cobbler's stitch, using fine, straight needles (No. 14 or 16) and fine black silk sterilized in white vaseline. If the wound is transverse, the suture staff (page 52) may be placed under the vessel, a guy suture of the usual material is inserted at one end of the wound and wrapped around an upper button on the long shaft, and another guy suture is placed at the opposite end of the wound and fastened to a button on the short shaft while it is being compressed toward the long

shaft. When the short shaft is released, it will make tension on the wound, and evert the intima. A cobbler's stitch can then be placed with the threaded ends of the guy sutures, as in suturing the first third of an end-to-end union. Care should be taken to secure the beginning of the suture line by going well beyond the wound and taking a back stitch. Occasionally a transverse or a lateral wound may be so inaccessible that neither of these methods can be used. In such instances a long guy suture may be placed at each end of the wound and held by an assistant while the wound is closed with a continuous overhand stitch of black silk in a curved, round needle (a number three French intestinal needle) sterilized in vaseline. There will be more leakage from the needle-holes after this method and thrombosis is more frequent, but in deep wounds it may be the only technique applicable.

CHAPTER V.

LATERAL ANASTOMOSIS OF BLOOD-VESSELS, AND REVERSAL OF THE CIRCULATION.

Lateral anastomosis of blood-vessels is used either in uniting a vein to a vein, as in the Eck fistula when the portal vein is joined to the vena cava, or in uniting an artery to a vein when it is desired to reverse the circulation. The indications for Eck fistula are few, if any, so far as its clinical application is concerned. The operation was described by Eck, a Russian surgeon, in 1877, and again in 1879. It has been performed a few times by German surgeons in cirrhosis of the liver,[1] but the metabolic products from the portal circulation sooner or later produce a toxic effect when discharged into the general circulation at a rate as great as the Eck fistula permits. Again, it is possible that the ascites may be due to irritation of the peritoneum and not solely to portal obstruction.

The indications for reversal of the circulation are still under much dispute. Halstead and Vaughan [2] reviewed the literature and reported personal experience. They conclude that the operation for reversal of the circulation has no practical value. Coenen, of Breslau, opposes the operation and gives his reasons at some length. They are that the valves must be forced, that it is probable the arterial blood following the route of least resistance goes through the first anastomotic vein back to

1 Rosenstein: German Surgical Congress, 1912.
2 Surgery, Gynecology & Obstetrics, January, 1912.

the heart and rarely if ever reaches the terminal branches of the vein, that in arteriovenous aneurism it takes weeks and sometimes months for valves to be forced sufficiently to detect pulsation in the smaller veins, and that the arterial blood in venous capillaries must have some manner of return which has not yet been fully studied. There are many pathological conditions in man such as arteriosclerosis, thrombo-angeitis obliterans, diabetes and Raynaud's disease that do not occur in experimental work. When the vessel itself is diseased at the site of the anastomosis, or when the veins are involved in the disease, reversal of the circulation is useless. When gangrene has already occurred, of course, operation for reversing the circulation cannot bring relief.

The practical utility of reversal of the circulation is doubtful. Some experiments which the author has recently performed and which are not yet ready for full report seem to show that in reversal of the circulation the blood returns to the heart by anastomotic venous branches a short distance below the site of the operation and that the arterial blood in a reversed femoral vein never reaches the foot and usually goes but little below the knee.

If the circulation is to be reversed, it should be done by lateral anastomosis and not by an end-to-end union. When the vein and artery are both cut across and the artery is united to the vein end-to-end, the distal channel of the artery is sacrificed, whereas if lateral anastomosis is performed and the vein ligated on the cardiac side, there will be two channels for the arterial blood instead of one. The original arterial channel is not put out of commission and at least no harm will be done even if no good is accomplished. This was originally pointed out

by J. B. Murphy and has later been demonstrated and insisted upon by Bernheim and others.

When the main artery to a limb is partially occluded and the veins are healthy, the arterial blood in the capillaries is probably drained off more quickly than normal. Thus the tissues are not bathed with arterial blood sufficiently long to be nourished properly. Obstructing a large vein may prevent this rapid passage of arterial blood and so equalize the circulation and improve the condition of the limb. In this way may be explained some of the reported improvements that have followed reversal of the circulation in a limb, particularly after the end-to-end method. Ligation of the femoral vein should be equally beneficial.

When doing a lateral anastomosis of artery and vein, Bernheim and Stone [3] recommend making the opening in the vessels by transfixing them with a cataract knife and cutting from within out about one-third of the circumference. The vessels are then cleaned with normal salt or Ringer's solution, anointed with liquid vaseline, and united by a continuous suture of fine silk.

Bernheim and Boegtlin [4] discuss the question of whether an Eck fistula is compatible with life and describe a new method for making this fistula. The portal vein and vena cava are first sewed together with a small curved needle and silk, using a continuous suture and No. 3 curved, French intestinal needle with double thread. Another row of sutures is made parallel with this and an especially constructed scissors with sharp points is partly opened, and one blade plunged into the vena cava and the other into the portal vein. The partition is then cut. A previously inserted suture is

3 Annals of Surgery, October, 1911.

4 Bulletin of Johns Hopkins Hospital, February, 1912, page 33.

quickly tied at the point of the puncture of the scissors. They claim that Eck fistula in dogs is consistent with life for a long period of time provided the diet is regulated, though certain hepatic functions are decreased when an Eck fistula is present, notably, tolerance for sugars, the formation of bile, and the hemolytic function of the liver.

The technique of Bernheim is similar to that of Sweet, who, in 1904, described a method in which a fine platinum wire was passed into the veins and an electric current connected, after the two rows of sutures had been placed, so burning an opening.

The technique of Carrel and Guthrie involves dissecting the vena cava and the portal vein and clamping them above and below the site of operation, which is difficult and tedious. The union is made with straight arterial needles.

If a lateral anastomosis is to be done on easily accessible vessels the technique is simple, but if the vesesls are difficult to expose, or if hemostasis cannot be complete, it becomes very trying. In an effort to standardize a technique that could be used in all cases of lateral anastomosis, whether in making an Eck fistula, or in uniting an artery and a vein in a difficult location, the author has devised a forceps that takes a lateral hold either on the entire caliber of each vessel, or on any portion of it as desired. The necessity for such a forceps was suggested by an operation done by the author at the clinic of Prof. W. L. Rodman, in Philadelphia, through the courtesy of Prof. Rodman. The case was an arteriovenous aneurism of the femoral artery and vein, too close to Poupart's ligament for the application of a tourniquet. After dissecting the artery and vein above and below the aneurism, placing Crile clamps on these vessels above and below the lesion, clamping the

profunda and controlling the internal branches, an attempt was made to dissect behind the aneurism. This was difficult and bloody, but it was thought that the blood was what remained in the sac and tissues. An incision into the communication between the vessels was followed by profuse bleeding that was controlled with considerable difficulty. It was suggested by Prof. Rodman and by Dr. Stewart Rodman, who kindly assisted in the operation, that a forceps that could clamp these vessels before dividing them would be advantageous. On looking up the matter afterward, the author found three kinds of forceps for clamping vessels for lateral suture. One was Joani's clamp.[5] The author has never seen this instrument but from the illustration the points appear frail and the handles are at such an angle to the blades as to interfere with suturing. The forceps of Stewart,[6] the jaws of which consist of large ovals, could not be used in arteriovenous aneurism. The instrument of Jeger,[7] a diminutive Roosevelt gastro-enterostomy clamp, has straight blades and the middle blade is objectionable. It was devised for making an Eck fistula. After experimentation and several changes a model was devised that seems to obviate the objections of the other instruments (Fig. 35). These forceps for lateral suture are five inches long, have thin, well-tempered curved blades with longitudinal grooves, and handles that extend in the axis of an imaginary line drawn from the tip to the heel of the blades. The blades fit accurately but are soft enough to be clamped on the skin of the forearm without pain. They can hardly injure the intima but to make this even surer soft, pure rubber tubing is slipped over the blades. The tubing should not be too

5 Keen's Surgery, Vol. 5, page 128.
6 Journal A. M. A., August 20, 1910.
7 Presented at German Surgical Congress, 1912.

close to either the heel or the tip of the blades as this might interfere with the pressure in the middle of the blades and so cause leakage. Such forceps can be used for suturing lateral wounds of large blood-vessels without entirely obstructing the blood-current. In creating an Eck fistula, the axis of the handles makes it possible for the handles to lie flat in the abdomen and so be out of the way. These forceps can be used where no tourniquet

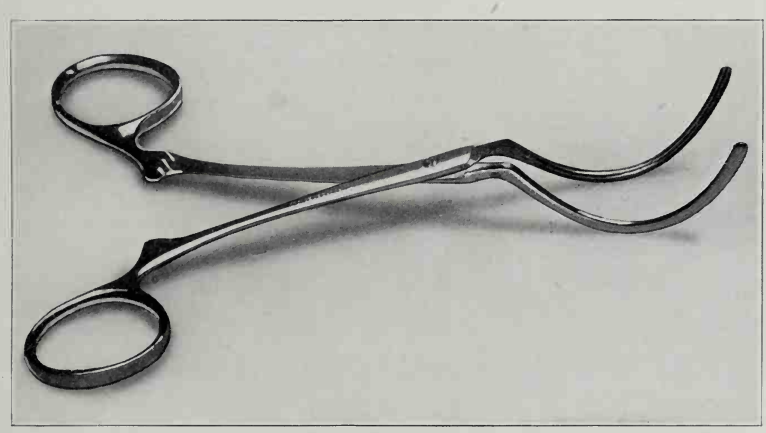


Fig. 35.—Forceps for lateral blood-vessel suturing. They are made with very light blades which can be clamped on the skin of the forearm without pain. The handles lie in the axis of a line drawn from the tip to the heel of the blades. In this way the handles will lie flat even in a deep wound and be out of the operator's way. In order still further to prevent injury to the intima, the blades may be covered with soft rubber tubing.

can be applied, as on the iliac vessels; or in operations on an arteriovenous aneurism where hemostasis is not satisfactory by other means. Even where hemostasis is complete, they serve to steady the walls of the blood-vessel while sutures are inserted and lessen the amount of intima exposed, so preventing it from drying.

These forceps have other uses than for lateral anastomosis, or the cure of arteriovenous aneurism. For instance, they can be employed for hemostatic forceps instead of the Crile clamp, acting in the same manner as

the forceps of Matas, which are designed for temporary occlusion of the vessel. As the blades are very soft, they can be quickly applied and locked without fear of injury to the intima. The author has also used the forceps satisfactorily in a gastro-enterostomy in an infant four weeks old when an operation was necessary on account of pyloric stenosis.

In lateral anastomosis of blood-vessels, whether uniting veins as in Eck fistula, or an artery to a vein, the same general principles of blood-vessel suturing mentioned in the chapter on end-to-end suture should be observed (see page 47). Asepsis should be rigid, hemostasis complete, the tissues should be handled gently, the adventitia should be removed, and after the intima is exposed the operation should be completed as quickly as possible by uniting intima accurately to intima and leaving but little foreign substance or suture material exposed in the lumen.

The vessels are exposed as fully as possible and are mobilized. It is not necessary to dissect both vessels entirely free from their beds, if they are close together. The adventitia over the parts of the vessel to be incised is dissected off and the lateral clamps described are applied, catching a deep hold on the vessel wall (Figs. 36 and 37). Both are applied in the same direction. It is better, if possible, for the vessel to be stripped of blood while placing the clamps. After both clamps are fastened, the vessels are anchored together with two stay sutures of fine silk sterilized in vaseline and placed at a little distance from the two extremities of the proposed anastomotic opening. The ends should be left long and the vessels manipulated by these stay sutures and not by the handles of the clamps which might slip or pull off with too much traction. An incision is then made into the

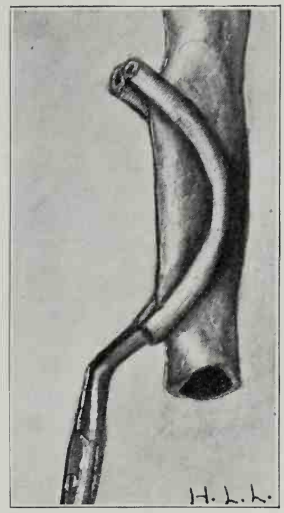


Fig. 36.—One forceps is shown covered with rubber and grasping the vessel preparatory to making a lateral anastomosis. If it is deemed unwise to occlude all of the vessel, only a portion of it can be caught.

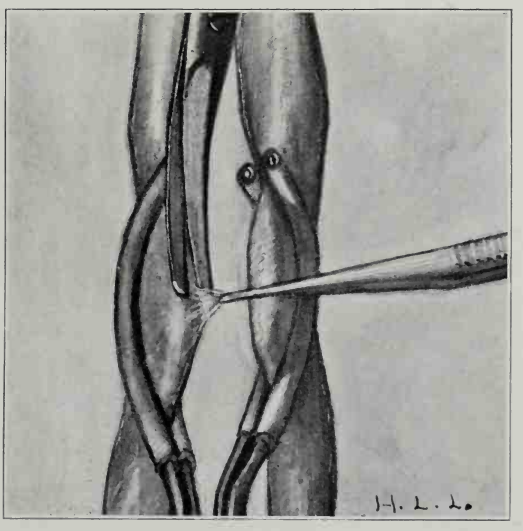


Fig. 37.—The two vessels to be anastomosed have been clamped. The adventitia is being lifted and cut away.

vessels (Figs. 38 and 39). This is done when an artery and vein are united by incising the artery transversely for about one-third of its diameter with sharp scissors (Fig. 39). The wound retracts, leaving an oval opening, and is smeared with white vaseline by dipping a finger of the left hand in vaseline and anointing the wounded ves-

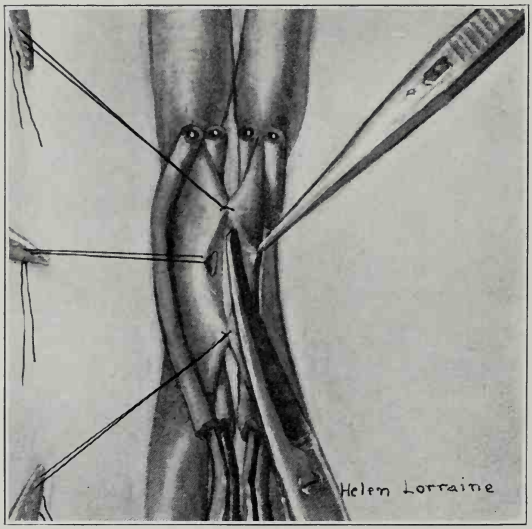


Fig. 38.—The openings in the two vessels are being made. The method illustrated in this drawing is that which should be employed in an Eck fistula. A small point of the vein is caught with the fine thumb forceps, lifted up, and the apex cut away with scissors parallel with the vessel. This is done on each side after the two stay sutures have fastened the veins together near the end of the proposed incision. After a small hole has been cut, a guy suture is inserted in the wall of the vena cava on the operator's left and is clamped with forceps but is not tied. Another suture is inserted in the wall of the portal vein on the operator's right by passing the needle from without inward. The needle is left attached but the suture is not tied. By pulling on these sutures, the small openings are exposed and can be enlarged as a slit with scissors. If a transverse opening is made here, the ends of the transverse incision will retract in the deep wound.

sel. The opening in the vein is made in a similar manner and should be slightly larger than the opening in the artery. A fine thumb forceps, or "frog" forceps, holds the vessel wall while it is being incised and enables the surgeon to make the opening more accurately. A tractor suture of fine silk sterilized in vaseline is placed in the left margin of the opening in the left vessel. This is not

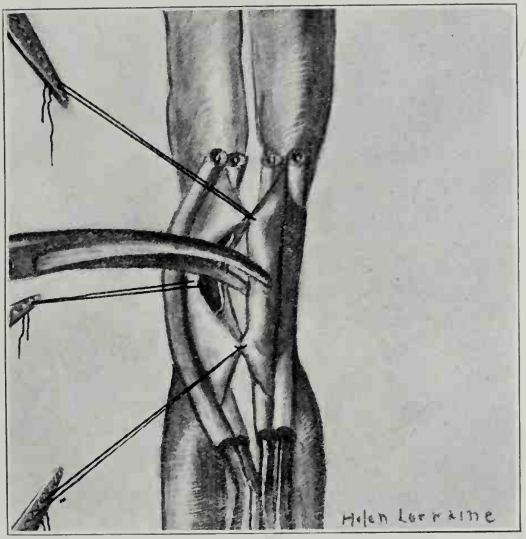


Fig. 39.—This shows a transverse cut, which is the method used in suturing an artery to a vein in making a lateral anastomosis for reversing the circulation. The transverse cut in the artery retracts into an oval opening. A similar opening is made in the vein. The tractor sutures are inserted as described under Fig. 38.

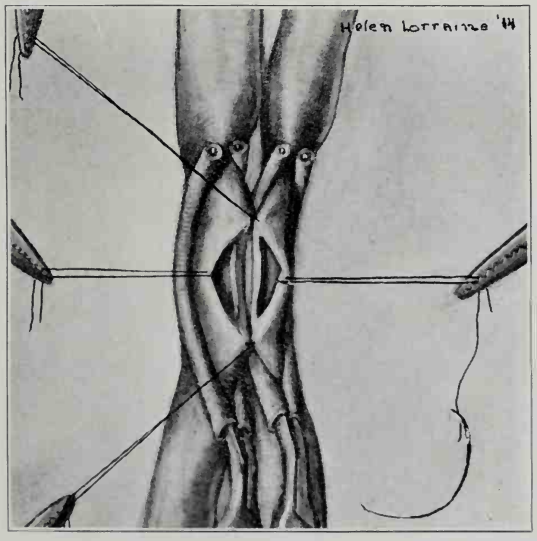


Fig. 40.—The two stay sutures and two tractor sutures are inserted and the openings are ready for suturing.

tied but clamped with mosquito forceps. A similar tractor suture is placed in the right margin of the right vessel, but the needle end is left attached and the suture is inserted from without inward (Fig. 40). The sewing is now begun with a small curved, arterial needle (or No. 3 French intestinal needle) and fine silk sterilized in vaseline, starting from the angle of the incision nearest the

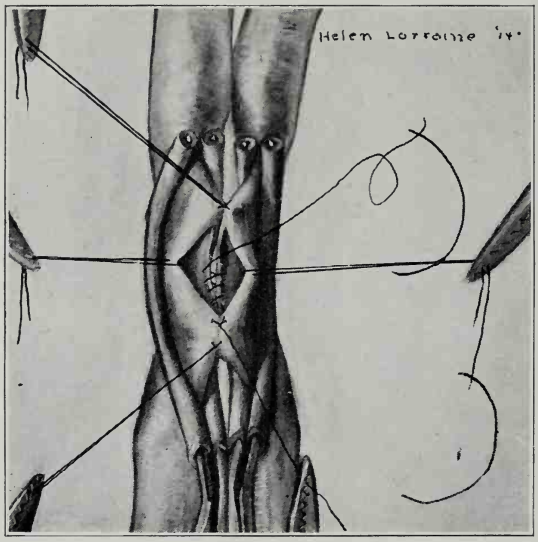


Fig. 41.—Suturing has been begun by using a very fine curved needle and black silk. It is started by going from without inward on one side and from within outward on the other side. The thread is then tied which leaves the knot *outside* of the lumen. The end of the thread is caught in a clamp. The needle is then thrust through the artery near the knot and suturing begins as an overhand continuous stitch. It is important to have the knot placed at the angle of the incision.

handle of the forceps. The needle is thrust through the wall of the vessel at the angle, going from without inward on one side and from within out on the other. The thread is then tied, holding the ends of the thread taut while running down the second knot to prevent slipping. This leaves the knot outside the lumen. The short end is clamped with mosquito forceps. The needle is again thrust through the blood-vessel wall near the knot, and a

continuous overhand suture is applied, uniting the intima accurately (Fig. 41). This can be easily done, using a mosquito forceps for a needle holder if necessary, and pulling on the tractor and stay sutures as indicated to expose the margins of the vessel wound. At the other angle care is taken to place the sutures closely for leakage is likely to occur here. After this angle has been

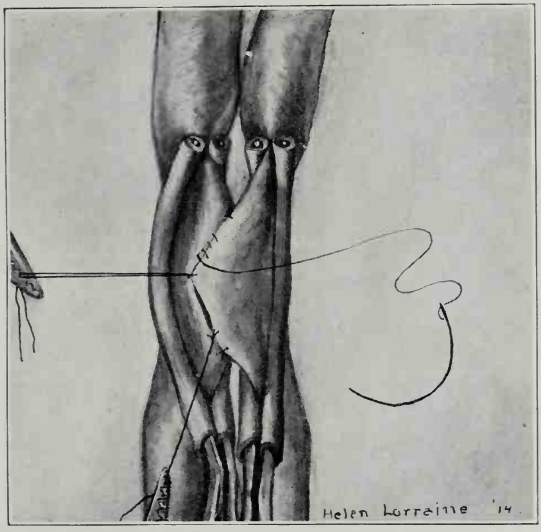


Fig. 42.—The suturing is continued and, after the upper angle is reached, the tractor suture on the left is removed and the needle and tractor suture on the right thrust through the margin of the left vessel. This is tied and when lifted up brings the sides accurately together and renders the suturing easier. After the thread has reached its original starting point, it should be carried about one stitch beyond the knot and tied snugly to the end that was clamped in forceps.

sutured, the left tractor suture is removed and the needle on the right tractor suture is thrust through the wall where the left tractor suture was and this suture is then tied (Fig. 42). The excess of vaseline is squeezed out, the tractor suture is lifted up so as to evert the intima, and the sewing is continued as an overhand stitch. When the original knot in the continuous suture is reached, about one stitch is taken beyond it and the

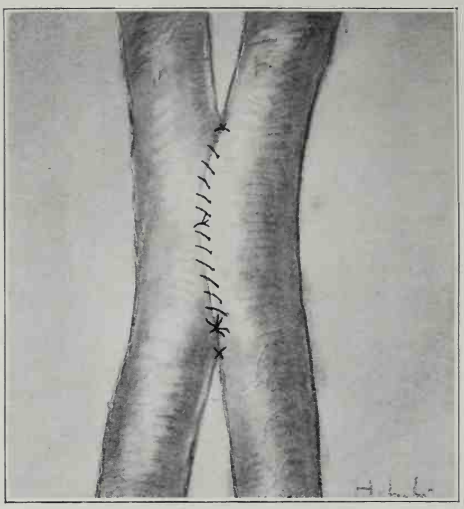


Fig. 43.—The lateral anastomosis is completed. The technique is practically the same for an Eck fistula or an arteriovenous anastomosis except as shown in Figs. 38 and 39.

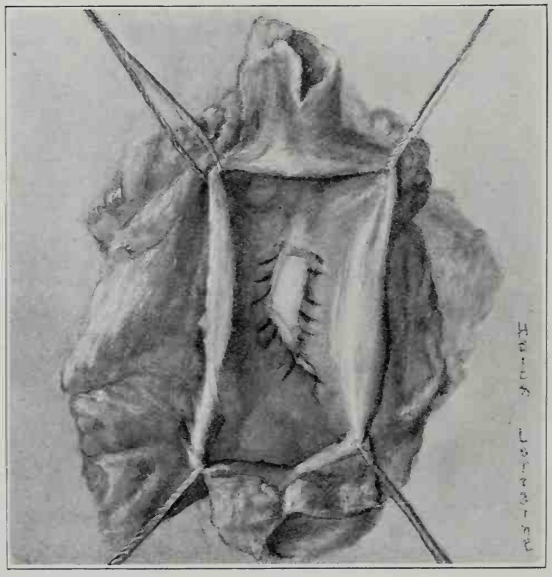


Fig. 44.—Drawing of a specimen of an Eck fistula in a dog six days after the operation. There is no thrombosis. Magnified about three times.

thread tied to the end that was left clamped in mosquito forceps (Fig. 43). The clamp from the vein is first slowly removed and the line of suturing slightly compressed with dry gauze. After a minute the arterial clamp is slowly relaxed and then removed if no markedly spurting point occurs. If it does, the clamp is reapplied and a suture placed at the spurting point. A ligature

Fig. 45.—Lateral anastomosis between the carotid artery and external jugular vein in a dog. Note the clear opening and just below the opening a valve in the vein. Drawing magnified about three times. Specimen was removed *twenty-one* days after the operation.

is put on the cardiac side of the vein to prevent the blood being immediately returned to the heart (Figs. 44 and 45).

In creating an Eck fistula, this same technique is followed except in incising the blood-vessels it was found that a transverse incision was not practical in large, thin vessels in such a deep wound, for it was difficult to suture the deepest portion of the transverse incisions.

The opening in the veins is made as follows: A very small bite of the vena cava about the middle of the proposed incision is caught with the "frog" forceps or with mosquito forceps and pulled up to form a cone whose apex grasped in the forceps is cut off with curved scissors (Fig. 38). A tractor suture is inserted in the outer wall of this small opening in a similar manner as in arteriovenous anastomosis. The same procedure is carried out on the portal vein and a tractor suture inserted from without inward and the needle left attached. These openings are then enlarged longitudinally as far as desired. The rest of the technique is followed exactly as described for arteriovenous anastomosis. It is possible, however, to use successfully a coarser needle and thread in Eck fistula than in arteriovenous anastomosis as the pressure is very low in the large veins.

CHAPTER VI.

TRANSFUSION OF BLOOD.

One of the applications of blood-vessel surgery is transfusion of blood. This operation, which consists in transferring blood from the vessels of one animal or person to those of another, is very old, though the earlier methods of performing it were far from successful. References to it are found in the Metamorphoses of Ovid, where the sorceress, Medea, took blood from healthy young men, mixed it with certain juices from vegetables, and then injected the mixture into the veins of old men who desired to renew their youth. The ancient Egyptians alluded to transfusion in their writings and probably practiced it. "The Book of Wisdom" of Tanaquila, the wife of Tarquin, refers to transfusion. It is also mentioned in the sacred book of the priests of Apollo, and in the works of Pliny and of Celsus.

The earliest authentic case on record occurred in 1492, when according to Villari's "Life of Savonarola," Pope Innocent VIII was transfused. He had fallen into a coma and could not be aroused. The blood of the pope was passed into the veins of a youth, "whose blood was transferred into those of the old man. The experiment was tried three times, and at the cost of the lives of the three boys, probably from air getting into their veins, but without any effect to save that of the pope."

Libavius advocated arterial transfusion by silver tubes as early as 1615.

Giovanni Colle, of Padua, in 1628, mentioned transfusion as a means of prolonging life.

In 1665 Lower, of Oxford, bled animals to the point of syncope and then revived them by the injection of blood from other animals. His results were published two years later. He used a quill to connect the artery of the donor to the vein of the recipient.

In the celebrated diary of Samuel Pepys is a note under date of November, 1666, in which transfusion of blood in dogs is described, one dog being almost bled to death and then transfused from another. Pepys says, "This noon I met with Mr. Hooke, and he tells me the dog which was filled with another dog's blood, at the college the other day, is very well and like to be as ever, and doubts not its being found of great use to men; and so did Dr. Whistler, who dined with us at the tavern."

In 1667, Denys, of France, repeated the experiments of Lower. He also transfused a fever patient with ten ounces of lamb's blood, and the patient recovered. He treated an insane patient by injecting several ounces of calf's blood and recovery from the insanity was reported. However, three months afterwards the disease recurred and Denys attempted to open the vein in the patient's arm, but found no blood. The patient promptly died and his wife accused the surgeon of killing her husband and the surgeon accused the wife of poisoning her husband. There was considerable excitement in Paris as a result of the case and the operation was very much discredited. Finally, a law was passed which practically forbade the performance of transfusion.

In 1667, a German surgeon, Mayer, performed transfusion of blood. Kaufmann and Purmann, in 1683, claimed to have cured a leper by the repeated injections of lamb's blood.

In 1682, Ettenmuller, of Leipsic, advised transfusion in fevers, scurvy, and hypochondriasis. Nuck seems to have had advanced views on transfusion. In 1714, he gave a history of transfusion in his book, advocating the employment of this operation when considerable blood had been lost, and advising against the use of blood of lower animals when transfusing man.

In 1749, Cantwell, of the Faculty of Paris, said transfusion should not be forbidden in desperate cases.

Michael Rosa, in 1783, made experiments in transfusion with lower animals and concluded that transfusing blood from one animal to another of the same species could be done without danger to life and that an exsanguinated animal could be revived by this means.

About this time, Laine claimed that the blood of calves and animals contained some material that was necessary for the development of peculiar tissues, such as horn and hoofs, which belong to these animals and therefore these elements would be disastrous when injected into the veins of a human being.

Harwood, in Cambridge, resuscitated an exsanguinated dog by transfusion in 1792, and in the same year it is reported that Russell successfully transfused for hydrophobia with lamb's blood.

In 1796, Darwin advised transfusion in certain diseases when proper nutrition was difficult.

In 1802, Scheele wrote an extensive review on transfusion and Diefenbach published an article reviewing transfusion in 1828.

In 1825, James Blundell, of London, revived the operation. He experimented on dogs by first bleeding them until pulse and respiration had ceased and then transfusing with fresh blood. He demonstrated that animals which were apparently dead for three or four minutes

could be resuscitated by transfusion, but transfusion was of no avail after five minutes. His work greatly stimulated interest in transfusion. Blundell's transfusions upon man were not as successful as those performed on the lower animals. His first cases all failed but afterwards he met with considerable success.

Dumas and Prevost, in 1825, first showed the injurious effect of the blood of one species upon that of another. About 1838, Bishoff introduced defibrination of blood for transfusion and concluded that venous blood is harmful but arterial blood is free from danger.

Panum and Brown-Sequard, in 1858, performed numerous experiments independently and both came to the conclusion that defibrination of the blood was one of the chief factors in the success of transfusion.

In 1863, Blasius collected one hundred and sixteen transfusions, all that had been done in the previous forty years. Fifty-six of these were reported as having resulted favorably. All were indirect transfusions and only two were from animals, though those two are said to have been successful. Of the fourteen cases in this series that were done with undefibrinated human blood all were failures. From the time of publication of this article until 1883, when von Bergmann published a paper on transfusion, this operation excited a great deal of interest. Transfusion of blood was tried indiscriminately, and Emerson in "Works and Days," in 1870, refers to it as "the boldest promiser of all, which in Paris, it is claimed, enables a man to change his blood as often as his linen."

In the Franco-Prussian War thirty-seven transfusions of defibrinated human blood were recorded and thirteen of these were reported to be successful. Geselius and Hasse, in 1874 and 1875, attempted to revive transfusion

of blood from animals to human beings. Lamb's blood was supposed to be particularly efficacious because the red blood cells are smaller than those of man. When Landois discovered, in 1875, that red blood cells are destroyed when mixed with blood of a different species, further attempts at transfusion from lower animals to man were abandoned.

By 1889, the opinion was generally held that it was exceedingly dangerous to inject the blood from one species of animals into another. More modern work has confirmed this idea.

Landois and others showed that blood from the same species might be transfused without destruction of the cells and that the blood would functionate normally. It began to be recognized that defibrinated blood was not free from danger and, in 1877, A. Koehler showed that the intravenous injection of defibrinated blood, even in animals of the same species, might cause clotting within the vessels because of the large amount of fibrin ferment contained in defibrinated blood. Cohnheim claimed that the injection of any blood in which coagulation had taken place was a grave error.

In 1883, von Bergmann reviewed transfusion of blood and came to the conclusion that only direct transfusion of blood from artery to vein was justifiable and here coagulation was likely to occur in the cannula. This seemed to put a quietus on transfusion for more than twenty years.

Transfusion in America was largely stimulated by the work of Crile, who began experiments in 1898, and by the work of Carrel, who so vastly improved the technique of arterial suture in 1902. According to Crile, Queirolo was the first to adopt an anastomosis tube in blood-vessel surgery as is employed at the present time. The method

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of Crile consists in using a cannula which varies from the smallest size of one and a half millimeters to three millimeters inside diameter. The size that seems best suited for the caliber of the artery is selected. The artery is dissected free, usually taking the radial artery, the lower end is tied and a small Crile clamp, or serrefine, is placed on the artery at the upper extremity of the wound. The vein in the forearm is next dissected, ligating it at the distal end and clamping it with a Crile clamp, or serrefine, at the upper angle of the wound. Care should be taken to select a large vein, which is usually found without difficulty about the elbow. These dissections can be done with local anesthesia, either one-fifth of one percent solution of cocaine or one-half of one percent of novocaine to which a small amount of adrenalin has been added. Tablets of novocaine and suprarenal extract are on the market. The region of the artery is infiltrated. The dissection should be made under a good light. Each bleeding point is caught with small mosquito hemostats so the field can be kept clear. Small branches of the radial artery must be clamped and tied with fine silk. The vein is freed in a similar manner. The artery is then cut across near the ligature and its adventitia removed, as described in the technique of suturing blood-vessels, by pulling it over the end of the vessel with the thumb and finger and cutting it off. Or it may be grasped with small dissecting forceps and cut away. The end of the artery is anointed with sterile vaseline. The vein is treated in a similar manner. The handle of the Crile cannula is clamped with a pair of hemostats and the vein threaded through the cannula, entering at its base at the handle. The vein is then caught by three mosquito hemostats and cuffed back over the cannula by traction on all three mosquito hemo-

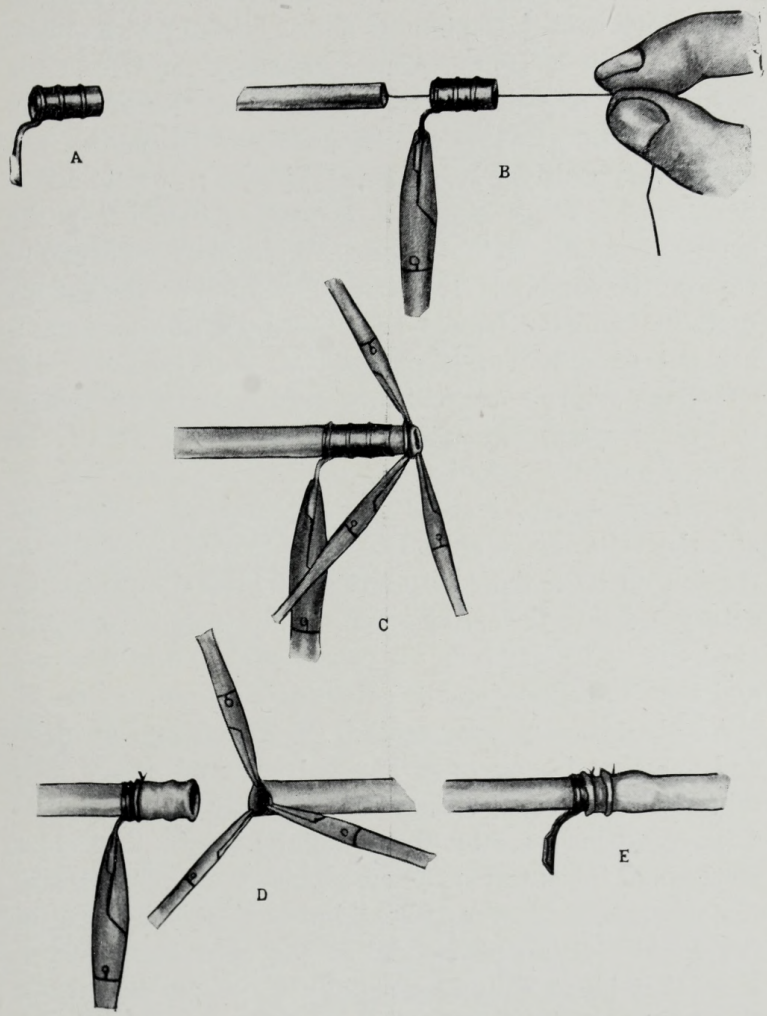

Fig. 46.—(A) Crile cannula. (B) Thread in the vein to draw it through cannula. (C) The vein is caught by three mosquito hemostats and cuffed back over the cannula, and at (D) is tied over the ridge next to the handle. It is lightly smeared with oil or vaseline and the artery slipped over the cuffed vein and fastened with a suture on the ridge farthest from the handle. (E) The operation completed.

stats at the same time. It is tied firmly with fine linen in the groove next to the handle and is covered with sterile vaseline, care being taken not to get any vaseline in the open end. A pair of closed mosquito hemostats is anointed with vaseline and inserted into the end of the artery very gently. It is opened gradually so as to dilate the artery. Three mosquito hemostats then grasp the artery at equally distant points and pull it over the cuffed vein on the cannula. It is tied in position on the groove farthest from the handle (Fig. 46). In this way nothing but endothelium is exposed to the blood current. Often the artery contracts very greatly and may appear to be too small, but after dilatation it can usually be slipped over the cuffed vein. Sometimes, three guy sutures may be used instead of the hemostats. Occasionally the vein or artery is kinked, but by making a little tension on it in the axis of the vessel first toward the artery and then toward the vein the kink may be straightened out. The clamp on the vein should be first removed and then the clamp on the artery is gradually loosened.

Another very popular method of transfusion of blood and one that is simple in application is by means of a tube. This was first brought prominently to attention as a practical measure by Brewer and Ligget. The older methods of tubes and syringes, such as the Aveling transfusion apparatus, were found impracticable because of the rapid clotting of blood. It has been known, however, that blood clots less rapidly on a smooth surface and in the presence of oil, or paraffin. Brewer's tubes are made of thin glass and vary in size. One end is usually larger than the other for insertion in the vein. They are slightly flared at each end to prevent the ligatures slipping off (Fig. 47). When ready for use the vein and artery are prepared, as already indicated,

though it is not necessary to dissect out quite as much artery or vein as would be the case if direct suture or a Crile cannula were used. The tubes are sterilized by boiling and just before being used are dipped in melted paraffin, the excess of the paraffin being shaken out of the lumen so as to prevent occlusion of the lumen. Cumol or liquid albolene or some paraffin oil may be used instead of paraffin. The artery is dilated by the insertion of a closed mosquito forceps covered with vaseline and

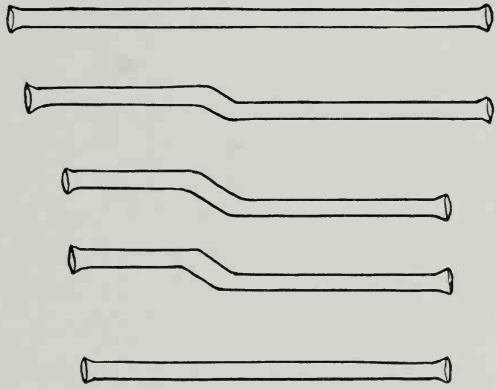

Fig. 47.—Brewer's glass tubes for transfusion. They are of different shapes and sizes, made from thin glass, and have flared ends to hold ligatures.

is so stretched that the small end of the tube can be introduced. The artery is drawn over this end by three mosquito hemostats. A ligature fastens the tube in the artery. The vein is also caught with three mosquito hemostats at equally distant points and a small spurt of blood is allowed to come through the cannula to expel the air. The large end of the tube is then inserted into the vein and fastened with a ligature. The clamp is removed first from the vein and then from the artery. Numerous modifications of the Brewer tube have been made.

Fauntleroy, of the United States Navy, has suggested

a S-shaped tube and makes the anastomosis from vein to vein. Bernheim, of Baltimore, constructs the tube of metal and in two pieces which are accurately fitted, and after their insertion into the vein and artery, respectively, the two halves can be joined and the blood current turned on (Fig. 48). He claims that in case of clotting, the clots can be removed without the necessity of taking the tube from the artery and the vein, as would be necessary if clotting occurred in the Brewer tube.

Modifications of the Crile cannula, which itself has been modeled on the tube of Payr, are numerous. Bernheim has modified the Crile cannula by prolonging the handle and placing three small hooks on the base of the cannula so the vein after insertion and being cuffed back can be fastened on to these hooks instead of being tied.

Hepburn has also modified the Crile cannula by adding a wide flange at its base which is perforated with four holes. These perforated holes aid in cuffing back the vein and in drawing the artery over the vein. Here sutures are used instead of mosquito hemostats for cuffing back the vein.

Robert C. Bryan and F. R. Ruff, of Richmond, devised an ingenious modification of the Crile cannula, which is made as a hinged tube. The vein is placed in the open cannula and the cannula is then closed. This avoids the necessity of threading the vein through the cannula, which is sometimes difficult. Bryan's modification includes a longer handle and a cannula of larger caliber than the regular Crile cannula (Fig. 49).

The cannula of Elsberg is built on the principle of the monkey-wrench. It can be enlarged or narrowed by turning a nut at the end of the handle (Fig. 50). The cannula is first opened and slipped under and around the artery and is then closed so as to compress the

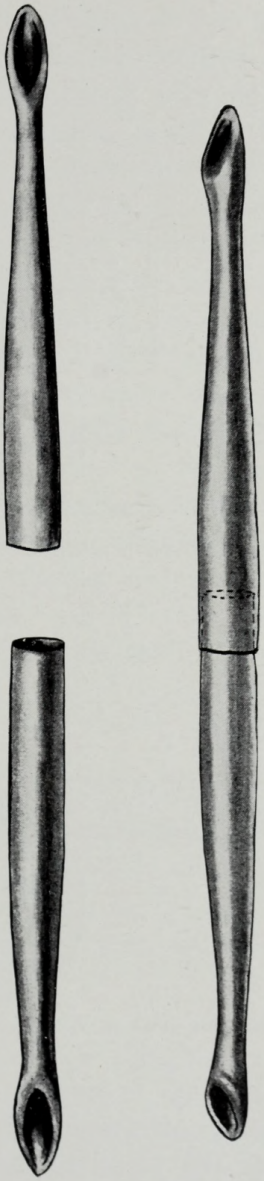

Fig. 48.—Bernheim's tube for transfusion. It is made in two parts which can be inserted separately into donor and recipient and then joined.

artery. The artery is tied, cut a third of an inch from the cannula, cuffed back over the cannula, and fastened on little hooks. The vein is exposed and the artery

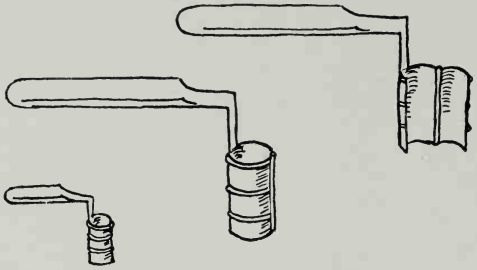

Fig. 49.—Modification of Crile cannula by Robert C. Bryan, which facilitates placing the vein in position.

on the cannula is slipped through a small slit in the vein. The cannula is then gradually opened until blood flows freely and until the wound in the vein is tense and does not leak.

Ottenberg employs a silver ring with two grooves on

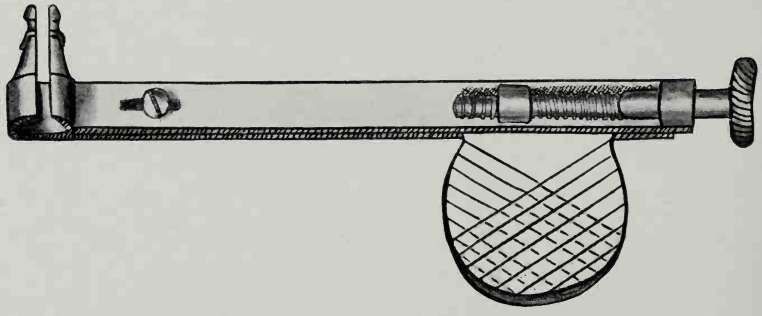

Fig. 50.—Cannula of Elsberg which works on the principle of the monkey-wrench.

its surface. The technique of using it is similar to that of Crile, except that he has a special instrument to hold the ring and fastens the vessel to the ring with silver wire.

Soresi employs double cylinders, which open on a

pivot. These cylinders slide on a small bar. The vessel is placed in the open cylinder, which is then closed, and the vessel is cuffed back over each cylinder and caught on hooks, which hold it in this position. The cylinders are adjusted on the sliding bar until the intima of each vessel is in contact, then the blood stream is turned on. He advocates vein-to-vein transfusion.

Janeway uses for transfusion an instrument consisting of two parts, which may be joined together and fastened securely, each half resembling a thumb forceps, each blade of which terminates in half a cylinder. The vessels are placed within the cylinders which are then adjusted by the thumb screw on the blade of the forceps. Each vessel is cuffed back. The two halves are joined together by means of a shoulder from one-half of the instrument which is called the male half and fits into a socket in the other half of the instrument, the female half. If desired and one vessel is much larger than the other the smaller vessel can by this instrument be invaginated into the larger vessel and sutured in this position.

Frank and Baehr advise that preserved blood-vessels be used as the links between the artery and vein in transfusion. The end of each link is fitted with a Crile cannula and the link cuffed back. In transfusion one end of the link is inserted into the vein and the other into the artery.

Hartwell suggests stripping the adventitia from the end of the artery and then rolling some of it back so as to form a ridge about one and a half inches from the cut end of the artery, which is well anointed with vaseline and inserted into the vein by means of three sutures of fine silk passed at equally distant points through the cut end of the vein. The vaselined end of the artery is

fixed in position by passing one of the sutures through the ridge of adventitia on the artery. The surplus circumference of the vein is taken up by a small clamp or by the other two sutures.

Dorrence and Ginsburg advocate vein-to-vein transfusion. The advantages they claim are that it is easier and that there is no danger of dilatation of the heart. Two superficial veins are connected on the forearm usually by means of a cannula such as the tube of Brewer, or by the cannula of Crile. The distal end of the vein in the

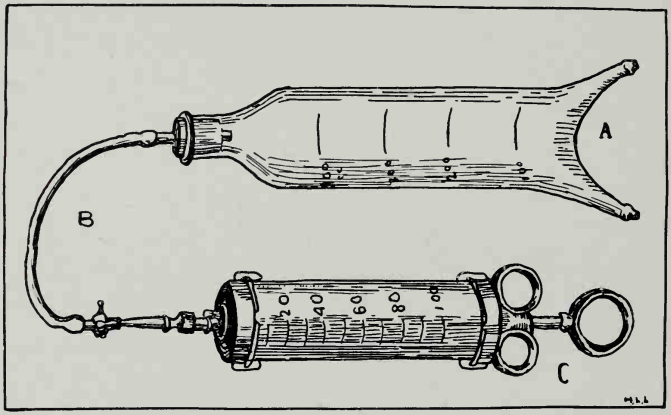

Fig. 51.—Curtis and David's apparatus for transfusion.

donor is connected with the proximal end of the vein in the recipient. A light tourniquet on the arm of the donor above the point of anastomosis hastens the flow.

Indirect transfusion may be done by drawing the blood into a large syringe that is coated with albolene or liquid vaseline, and then injecting it immediately into the vein of the recipient.

Curtis and David used a Y-shaped cannula for vein-to-vein transfusion (Fig. 51). The cannula is coated with sterile vaseline, one arm is inserted into the proximal end of the recipient's vein and the other in the distal

end of the donor's vein. A glass syringe, the interior of which has been coated with vaseline, is now fitted to the neck of the cannula. The vein of the recipient is clamped and the vein of the donor is loosened while the syringe draws up blood, then the vein of the donor is clamped and the clamp on the vein of the recipient is released while the syringe forces the blood into the vein of the recipient. This procedure is repeated until the proper amount of blood has been transferred.

Tuffier, of Paris,[1] describes a simplified technique for transfusion in which he uses three silver tubes coated with paraffin. He connects the internal saphenous vein of the patient to the radial artery of the donor. Lateral wounds are made in the vessels and one end of the tube is inserted in the artery and the other end introduced into the vein. The operation is on the principle of Brewer's tube.

Other measures, such as bleeding the donor into salt solution and injecting the mixture intravenously, have been suggested.

Kimpton and Brown [2] devised a large glass tube which is coated with paraffin on the inside. The upper end is closed with a cork stopper. A side tube runs out from the main tube a short distance below the cork. The lower end of the tube is drawn out into a small cannula which is bent so as to form a trap when the large tube is placed horizontal. From the last bend the cannula should not be more than two or three inches long and should taper gradually into a bevelled and smooth point about two to three millimeters in diameter (Figs. 52 and 53). When ready for use a small piece of paraffin is placed in the cylinder, the cork inserted, and the whole

1 Presse Medicale, July 31, 1912.
2 Journal A. M. A., July, 1913, page 117.

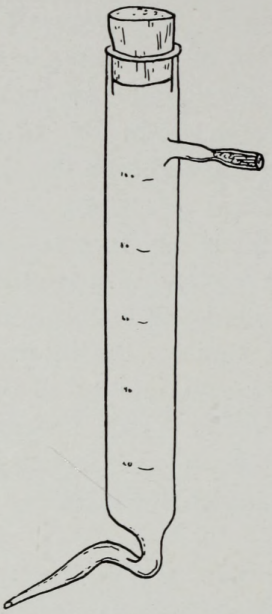

Fig. 52.—Kimpton and Brown's apparatus for transfusion.

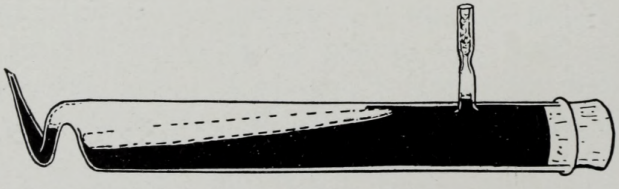

Fig. 53.—Kimpton and Brown's cannula in horizontal position, showing the trap which prevents the entrance of air in the cannula.

apparatus wrapped in a towel and sterilized in the autoclave with the dressings. After removing the tube it is heated over a Bunsen burner and the paraffin carefully coated over the interior of the tube, the excess running out of the cannula. The cannula should then be cooled as quickly as possible without breaking. Sterile absorbent cotton is placed in the side tube. When in use the cannula is inserted into a wound in the artery and the tube held vertically until it is filled with blood. The tube is then brought to a horizontal position and the cannula inserted into the vein. The tube is again brought to a vertical position and the blood allowed to run into the vein. A bulb, as from a Paquelin cautery, is attached to the side tube and with very little air pressure the apparatus empties itself through the cannula. The cannula may hold 250 cubic centimeters and two cannulas may be used so one can be filled while the other is being emptied. The vein of the donor, instead of the artery, may be used.

Edward Lindeman,[3] of New York, describes a new method of indirect transfusion. A small needle, the size of a small aspirating needle, surrounded by two cannulas is used to enter the vein of the donor and another similar set for the recipient. The cannulas may be lined with a film of albolene. A series of Record syringes that fit the outer cannula and of a twenty cubic centimeter capacity is sterilized. When the vein of the recipient is entered and blood appears in the cannula a syringe filled with warm, normal salt solution is immediately attached to the cannula and a very slow flow of salt solution is established to prevent clotting in the cannula. The veins of both donor and recipient are treated similarly. An empty syringe is then fitted to the cannula in

3 American Journal of Diseases of Children, July, 1913.

the donor by an assistant, filled with blood and passed quickly to the operator, who at once injects the blood into the cannula of the recipient. A little normal salt solution is injected through the cannula of the recipient after each syringe full of blood to prevent clotting in the can-

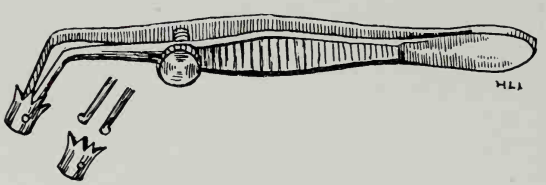

Fig. 54.—Landon's cannula with forceps for applying it.

nula. Each syringe should be thoroughly washed out with normal salt solution before being used again. No skin incision is necessary. Usually the median basilic is the vein punctured, with a light tourniquet on the donor. In infants the external jugular is better.

L. H. Landon,[4] of Philadelphia, describes a new self-

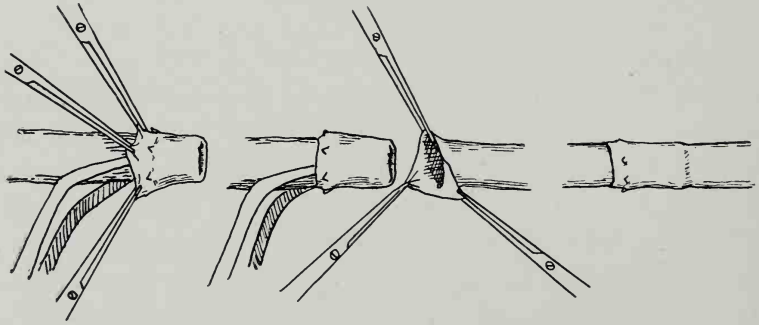

Fig. 55.—Method of using Landon's cannula.

retaining tube for transfusion of blood (Figs. 54 and 55). This tube is a short cannula of metal made in three different sizes. One end of the tube is smooth and the other has five sharp points which are slightly everted. Two perforations in the side of the cannula enable it to

4 Journal A. M. A., August 16, 1913, page 490.

be held by special forceps. Either the artery or the vein is threaded through the cannula, and cuffed back; then the other vessel is drawn over. Both are fastened to the hooks.

H. A. Fraund,[5] of Detroit, describes a method of transfusing fresh blood by means of a well-fitting aspirating syringe holding twenty cubic centimeters, a two-way stop cock irrigator with a glass cylinder attached, and two tubes with needles leading from each tube. The glass cylinder has a small stop cock and the whole apparatus is mounted on an inclined wooden base. Normal salt solution is poured into the glass cylinder and taken into the syringe and both needles are then held so that the normal salt solution will go through them and remove the air. Blood is then drawn through one of the needles inserted into a vein and thoroughly mixed with the salt solution. It is then introduced into the recipient.

Satterle and Hooker[6] describe an indirect method of transfusion of blood in which the blood is drawn into a paraffin lined receptacle and injected into the vein of the recipient.

B. F. McGrath, of the Mayo Clinic, has devised three different methods for transfusion in order to meet the various conditions as to size of artery, measurement of blood, etc. When exact estimation of amount of blood is required, he recommends a modification of the old Aveling operation. A rubber bulb of about thirty cubic centimeter capacity and having two small tips is filled with salt solution. The tips are fastened into the veins of the donor and recipient, respectively, the vein of the donor is clamped with a serrefine, and the bulb squeezed, forcing the salt solution into the vein of the recipient.

5 Michigan State Medical Society Journal, September, 1913.
6 Archives of Internal Medicine, January, 1914.

The serrefine is then transferred to the vein of the recipient, and the bulb, released, draws in blood from the donor. The serrefine is again transferred to the vein of the donor while the bulb is compressed. In this manner thirty cubic centimeters of blood are forced into the recipient with each emptying of the bulb. There is some danger of forcing in clots by this method. McGrath [7]

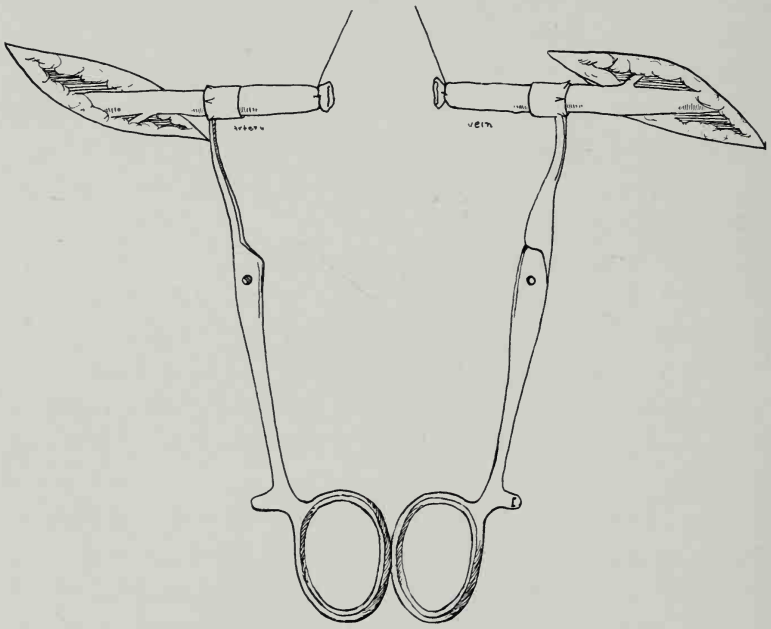

Fig. 56.—Transfusion forceps of McGrath.

has also a transfusion forceps which can be separated and locked like obstetrical forceps. At the end of each half is a short cannula through which the blood-vessel is threaded, cuffed back, and fastened on small hooks (Fig. 56). The forceps are then put together, gently locked and the blood turned on. McGrath [8] advises transfusion

7 Journal A. M. A., January 3, 1914.
8 Journal A. M. A., April 25, 1914.

by suture when the vessels are small and has devised a tripod which fits over the artery, the three legs being points of attachment for the three guy sutures.

A. Crotti [9] describes his method of using indirect transfusion of blood by means of a syringe with a blunt needle in which the blood is aspirated into the syringe and injected into the recipient. The procedure can be repeated if the syringe is washed out carefully with normal salt solution each time after the injection. This is similar to the method of Lindeman.

W. L. Moss,[10] of Johns Hopkins, describes a method of indirect transfusion with defibrinated blood. The blood is withdrawn from the donor's vein into small glass flasks by means of an aspirating needle and a rubber tube lined with a thin coating of paraffin. The blood is defibrinated by being shaken in the flask with a half ounce of glass beads. It is then filtered through sterile gauze into an infusion bottle containing 300 cubic centimeters of normal salt solution and injected into a vein of the recipient. The chief objection to the use of defibrinated blood in transfusion was pointed out by A. Koehler, von Bergmann and others (page 99) and consists in the fact that there is an excess of fibrin ferment which may cause clotting within the vessels.

9 Surgery, Gynecology & Obstetrics, February, 1914.

10 American Journal of the Medical Sciences, May, 1914.

CHAPTER VII.

TRANSFUSION OF BLOOD.
(Continued.)

Transfusion is divided into two types, the direct and the indirect. In the former, blood flows in a continuous stream from the donor to the recipient, while in the indirect method the blood is drawn from the donor and injected into the veins of the recipient. Sometimes the blood is diluted with salt solution or defibrinated before being introduced into the recipient, and frequently it is injected quickly before it can clot.

In considering the various methods of transfusion, two things should be borne in mind, efficiency and simplicity. The objection to any special apparatus is, of course, obvious. Usually, this apparatus consists of cannulas that are required to fit the various calibers of the artery or vein. In cannulas that permit contact of blood with their walls, such as the Brewer tube, there is the possibility of clotting to be considered. If these instruments work satisfactorily, nothing more can be desired, but if the proper size is not at hand, if the device is out of order, or if a clot forms in the cannula, it may be impossible to do the transfusion, which is always an operation of great necessity. The suture method avoids these objections.

The vein in the recipient should be chosen near some branch. The branch is dissected out, divided and clamped with mosquito forceps. The main vein is then clamped at the proximal end of the wound with a serre-

fine, ligated at the distal end and divided and sutured to the artery, as described under the technique of arterial suturing (pp. 50–67). The arterial suture staff makes it as easy to suture a small artery to a large vein, if the disparity is not too great, as to suture vessels of equal caliber (Fig. 57). After the suturing is completed the clamp on the vein is removed first and the clamp on the artery is gradually loosened. If there is no spurting point, but merely a slight oozing, the guy sutures to the staff can be cut and the instrument removed. If for any reason clotting occurs or an excess of vaseline blocks the lumen, the finger can be placed on the vein of the recipient just above the venous branch, and the mosquito forceps released, while the thumb and forefinger of the other hand gently manipulate the sutured area. The thrombus is blown out through the venous branch. Sometimes a valve exists in the branch and in this case it can be overcome by inserting a closed pair of mosquito forceps, which have been anointed in vaseline, and gently dilating the valve. Not infrequently in transfusion the artery contracts to such a degree as almost to stop the flow of blood. If the artery is kept covered with gauze wrung out of warm salt solution, this is not so likely to occur. Sometimes, however, even in spite of this, contraction of the artery is marked. If it is too great, a smooth silver probe, such as a lachrymal probe, is thoroughly anointed with vaseline, introduced through the venous branch, and carried well up into the radial artery. This procedure will at once be followed by a full flow of blood, but it cannot be done where a cannula is used, only when the union is made by sutures. Usually after four or five minutes a clot will reform on account of the injury by the probe. The probe can then be reinserted. A strong flow of blood for fifteen minutes is ordinarily sufficient, and it is better

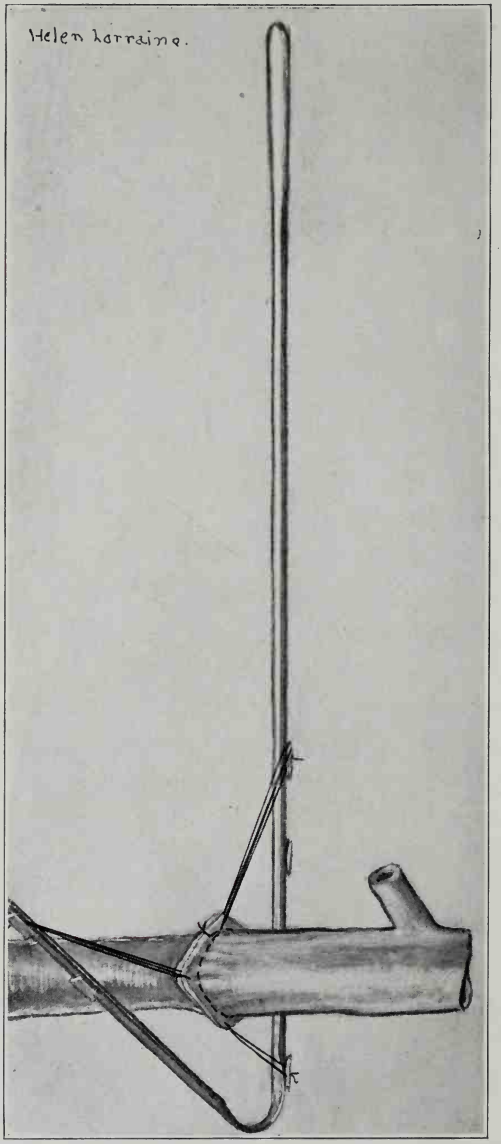

Fig. 57.—Showing suturing applied to transfusion of blood. On the right is a vein which is somewhat larger than the artery. The vein has a branch through which a smooth probe covered with vaseline can be inserted and pushed up into the artery if an obstruction occurs, or if the artery contracts too much. By pressing on the main trunk of the vein, clots may be blown out through the branch.

to use the probe several times in this manner than to do the whole operation over again. If for any reason the suture line is unsatisfactory, it can be cut out close to the sutures, so sacrificing only a small portion of the artery and vein; whereas when cannulas are employed, so much of the artery or vein has to be cut away with the cannula that often not enough of these vessels is left with which to do the operation again.

The dangers of transfusion that are dependent directly upon the operation are clotting, formation of a thrombus or embolus, the entrance of air, too great rapidity of flow, and infection in the wound. The remedy for most of these conditions is obvious. The danger from thrombus formation has been greatly exaggerated, unless large tubes are used, or there is great carelessness at the time of the operation. If large tubes are permitted to contain clotted blood which is loosened, trouble may result, but the minute thrombus that would ordinarily result from the line of suturing or from a small cannula, such as the Crile cannula, would hardly injure the patient if the clot is not septic. It has been proven experimentally that it is very much more difficult to create an infarct in the lungs than is usually supposed. In animals, sterile mustard seed may be introduced into the veins without the formation of infarcts in the lungs unless the bronchial artery supplying the lobe in which the seed lodges is ligated. However, it is just as well not to have thrombi introduced into the recipient and by careful technique and the selection of a vein with a branch near the point of anastomosis, as has been suggested, their introduction should be obviated.

The danger from entrance of air has also been greatly exaggerated, as a small amount of air is rapidly dissolved in the blood stream. Large amounts introduced

in the big veins of the neck, axilla, or groin are, of course, dangerous, but the small quantity that would get in during a direct transfusion as ordinarily performed would probably not be of serious consequence. In the use of a syringe, however, as recommended by some in the vein-to-vein transfusion, or in the rubber bulb of the Aveling apparatus, it is quite possible to introduce what would be a fatal amount of air.

Sepsis is guarded against by proper aseptic technique. The overcrowding of the heart by too much blood should be watched for. If the blood is flowing too rapidly the artery may be compressed between the finger and thumb so as to diminish the flow or check it entirely. The heart should be percussed and if there is any suspicion of overcrowding the heart or the slightest sign of enlargement, transfusion should be stopped temporarily or permanently. If the heart dilates, the patient should be placed upright, or in the reversed Trendelenburg position, and pressure made over the heart.

The proper amount of blood to be transfused can be estimated by the appearance of the recipient, particularly by the color of the skin, by the character and rate of the pulse and by the blood pressure, which may be taken at intervals. Usually too little blood is introduced, but if a patient has been ill for a long time it is easy to transfuse too much. When the hemorrhage has been acute and the patient's organs have not had time to weaken or degenerate, as occurs after a long sickness or many hemorrhages, the blood can be introduced much more freely than in an individual who has been anemic for a long time, and whose heart and other organs has been suffering from the malnutrition. Here the strain of turning on suddenly too much blood might result disastrously.

In the indirect method either the whole blood is trans-

ferred before it has time to clot or the blood is diluted with salt solution and is then injected into the veins of the patient. The artery-to-vein direct method, particularly when the union between the artery and vein is done so as to approximate intima to intima, insures that the rich oxygenated arterial blood of the donor is directly transferred unimpaired to the right side of the heart. Certainly, a patient in need of transfusion with all organs operating at a low level of vitality needs nutritious arterial blood, which has already been oxygenated, more than the venous blood that contains the waste products of the tissue from which it comes. The indirect method has not only this disadvantage but the additional one that there may be fine changes when blood stands even a few minutes in a syringe that will render the blood less desirable than when it is directly transfused. The chief objection to the artery to vein method is that it may cause dilatation of the heart by giving an overdose. These symptoms come on gradually and can usually be prevented by stopping the transfusion when such symptoms first appear.

Problems Concerning the Donor.

The selection of the donor for transfusion requires some care. Usually, there is but little trouble in securing a donor if the matter is put frankly before the relatives and friends of the patient. It should be emphasized that the operation will be practically painless and without danger to the donor, and that no more blood will be used than is considered necessary. If an appeal of this kind is not heeded, sometimes money must be offered for a suitable donor. He should be selected without sentiment and with regard to what would be best for the recipient. As a rule young people, either male or

female, are the most acceptable. Their arteries are soft and they can stand the loss of blood much better than the old. Each donor should be carefully examined, particularly in regard to the possibility of syphilis, either hereditary or acquired. Of course, it would be unwise to use one who is septic in any form or who has tuberculosis, though the latter might be acceptable under certain conditions.

The amount of blood drawn from the donor is difficult to estimate, as the flow is dependent upon the blood pressure of the donor, the size of his artery, the resistance of the recipient, the duration of the flow and the size of the opening where the artery is joined to the vein. Most of these conditions vary continuously. The artery may contract from exposure to cold or the blood pressure of the donor may change from psychic causes, or from the loss of blood. The size of the opening may be altered by deposit of fibrin, and the resistance of the recipient will also be a variable factor. For these reasons it is best to be guided in the amount of blood transfused largely by clinical symptoms. If the color of the donor appears distinctly paler than normal and the pulse rapid, transfusion should be discontinued. If the condition is psychic and more blood is needed, it may be wise to stop for a while and then start the flow again. As a rule, however, it is best to discontinue entirely under these conditions. The excitement of the surroundings and the knowledge that the donor is proving of benefit to the recipient usually tend to hold up the blood pressure. If it falls rather rapidly from normal and reaches as low as 110 or 115 the transfusion should be stopped at once regardless of other symptoms. The artery of the donor should be ligated well up to the wound with catgut and due care should be taken to see that the wound in the

donor is not infected by any of the tissues or juices from the wound in the recipient. The wound should be closed with interrupted sutures or with a button hole stitch, leaving a small catgut or silkworm gut drain, as the length of the manipulations and the exposure of the wound often cause a mild infection.

Concerning the Recipient.

The chief danger to the recipient is from an overdose of blood. In transfusion as in every valuable therapeutic measure, the dose should be regulated; if too much blood is given the heart may be strained unduly, while with too little the required effect may not be obtained. If the flow is free, just as soon as the patient's color has improved markedly, his pulse has decreased in rate, and his blood pressure increased twenty to thirty points, it is best to discontinue the transfusion whether it has lasted ten or forty minutes. Twenty minutes is an average time, though with a young child or a thin patient this might be too long. The hemoglobin should be increased by about fifty or sixty percent of what it was before transfusion.

Cases of secondary anemia due to whatever cause, whether the result of small hemorrhages for a long time or of sepsis, sometimes become partly accommodated to the low grade of anemia. Byford [1] has called attention to this in women who have lost an excessive amount of blood from the uterus, extending over a long period of time. Sometimes the organs have become accommodated to a hemoglobin of forty or fifty and the patient will be apparently enjoying good health, but a little extra hemorrhage or strain will entirely break down the resistance. In transfusing such patients if an effort is made to double the hemoglobin, so much blood will be administered that

1 Surgery, Gynecology & Obstetrics, September, 1913.

the heart and other organs cannot stand the strain, and even if they do the patient is often uncomfortable with headaches and other symptoms that are only relieved when the hemoglobin falls. In acute hemorrhages involving a large loss of blood the hemoglobin can be brought practically to what it was before the hemorrhage occurred.

In fat persons the veins are small and it is sometimes very difficult to secure a vein in the forearm of proper size for transfusion. It is useless to attempt transfusion except with a vein that is larger than the donor's artery, preferably considerably larger. If the veins about the elbow are not large enough the basilic vein of the arm or the saphenous in the leg may be used.

The blood pressure of the recipient should be taken occasionally and when clinical symptoms and increased blood pressure, as mentioned above, indicate that enough blood has been transfused, transfusion should cease. Dilatation of the heart is preceded by a full and slow pulse with very little strength, by precordial pain, and often by dyspnœa and cyanosis. These symptoms, as a rule, come on gradually and at their first inception the transfusion should be stopped and the patient set up on the table, or placed in a reversed Trendelenburg position. Massage over the region of the heart should be done and small doses of nitroglycerine may be given. It is best to give both the recipient and donor from one-sixth to one-fourth of a grain of morphine with one 120th of a grain of atropine a half hour before the operation. This stimulates the heart and tends to quiet both donor and recipient. If the transfusion is done for such affections as illuminating gas poisoning, the recipient should be bled as much as he can reasonably stand before turning on blood for the transfusion.

The question of hemolysis, which formerly was considered a great objection, need not be seriously considered if a donor who is of the same race as the recipient and who, better still, is a blood relative is selected. If the transfusion is done for pathologic hemorrhage, or for pernicious anemia, hemolysis may result, but for secondary anemia due to repeated hemorrhages or acute anemia following a large hemorrhage, there is practically no danger from hemolysis with the selection of a proper donor. Hemolysis *in vitro* is so different from the conditions *in vivo* as to make it doubtful if a laboratory test of hemolysis between donor and recipient will be of any real advantage. No instances of serious hemolysis have been reported with a donor selected as just suggested except in pathologic hemorrhages, and in one of the most noted cases—that of Pepper and Nesbit—it seems possible at least that some hemolysis was present even before the transfusion.

However, if it is concluded to make a laboratory test for hemolysis the following method by Morris Fishbein [2] for the selection of a donor in transfusion of blood may be used. "So far as the blood of the donors to be tested is concerned, sufficient blood may be obtained from the ear; but in the case of the patient it would be better to draw the blood from the median basilic vein of the arm in the usual way because more serum is required. Three drops of the blood are added to ten cubic centimeters of a one percent solution of sodium citrate in physiologic salt solution. In this manner approximately a two percent suspension of the blood is prepared, the citrate preventing coagulation. The remaining blood is poured into a centrifuge tube and allowed to clot. With a clean needle the clot is loosened from the side of the tube and

2 Journal A. M. A., September 7, 1912, page 793.

the tube centrifuged for a few minutes to obtain an upper layer of absolutely clear serum. This completes the preparation of material, with the exception of the plate which is now to be described and which has been found to be very serviceable. On an ordinary piece of window glass, approximately two by four inches in size, which has been washed absolutely clean with water and ether, ten small circles are made with melted paraffin, assuming that a choice is to be made among five donors. If the melted paraffin is drawn up into a medicine-dropper, the circles are quickly made with the tip while gentle pressure is exerted on the bulb. Ten circles may be made with one medicine-dropper full of melted paraffin. In this manner ten paraffin cups are made, each of which will hold at least four drops. The circles are made in two rows of five each. In each cup in the first row is placed one drop of the suspension of the patient's blood, and in each cup in the second row are placed two drops of the patient's serum. To Cup one in the first row are added two drops of serum of Donor I, to Cup two, two drops of serum of Donor II, etc. To Cup one in the second row is added one drop of the blood of Donor I, and to Cup two, one drop of the blood of Donor II, etc. There are therefore required in such a set five drops of patient's blood suspension, and ten drops of patient's serum, and one drop of each donor's blood suspension and two drops of serum. With a narrow glass rod the fluids are mixed thoroughly, the rod being washed in citrate solution and wiped after each mixing. In practically all instances, iso-agglutination when present becomes visible macroscopically after half an hour at room temperature; the mixture can be inspected easily under the microscope also. It is obvious that in testing for iso-agglutination in larger groups, as in twenty, the greatest

advantage is to be derived from this method. It has seemed so simple and easy of performance in comparison with other methods that it was thought best to make a brief report of it."

Operating Room Technique.

The arrangement of the operating room should be so that the head of the recipient points in an opposite direction from the head of the donor. Two operating tables or two stretchers, for the recipient and donor, should be placed in such a position that the left arm of the recipient is in easy contact with the left hand and forearm of the donor. The hand and forearm of the donor should be in contact with the ulna side of the forearm of the recipient. A small table between the two stretchers serves for a place on which the arms of the donor and the recipient rest. There should be a stool for the operator and one for the assistant on the opposite sides of this table. A good light and an abundance of patience are necessary. It is well to talk to the donor and possibly the recipient during the operation so as to encourage them as much as possible. Local anesthesia should be used for both donor and recipient. One-fifth of one percent solution of cocaine can be employed, or, better still, one-half of one percent of novocaine to which a small amount of a suprarenal extract has been added. This latter anesthetic is sometimes safer than cocaine and with the suprarenal extract will last as long as cocaine. Tablets containing these two substances are on the market. The radial artery is exposed through an incision of about three inches. Mosquito forceps with which to clamp each bleeding spot should be ready. The field must be as dry as possible. The artery is handled gently and the little branches that come from it are clamped

with mosquito forceps and tied with fine black silk. The radial artery is ligated with catgut at the lowest end of the incision, the blood stripped up with the finger and thumb and a serrefine placed on the artery at the upper end of the incision. The vein in the recipient is then exposed. Grasping the skin over a prominent vein near the elbow with forceps, lifting it from the vein and cutting out a small patch of skin, will expose the vein quickly without injury and without the need of retractors. This oval exposure can be extended by a straight incision in any direction needed. The vein should be so selected that a fairly large venous branch comes off near the point of proposed anastomosis. A ligature is placed on the vein at the lower end of the wound and a serrefine clamp at the upper end. First the artery and then the vein are cut across near the ligature, the adventitia is removed, and the ends are anointed with white vaseline and united as has already been described after the technique for suturing blood-vessels.

Indications for Transfusion.

The field for transfusion may be roughly divided into anemia from loss of normal blood, anemia from pathologic hemorrhage, anemia due to the hemolytic action of some toxin, and shock. When anemia is due to either the direct or indirect hemolytic action of a toxin the decision as to transfusion must depend upon whether the source of the hemolysis can be eradicated. If, for instance, it is the toxin that is responsible for leukemia or pernicious anemia, where the new blood is soon acted upon by the agent that has already destroyed the blood of the recipient, transfusion is generally useless and is, indeed, hardly justifiable. Reports on transfusion for pernicious anemia and for leukemia are summed up by

Crile[3] with the statement that it has not been demonstrated that either of these diseases is favorably modified by transfusion, even in an early stage, and that in an advanced stage neither of them is benefited by transfusion. When we consider the fact that the reaction from a hemolytic agent may be slightly different on the donor's blood from that of the recipient, we can readily understand that there is a possibility of adding other toxic products formed by the destruction of the donor's blood within the vascular system of the recipient that possibly might not be produced when the recipient's blood is the sole source of the hemolytic material. The direct cause of hemolysis in these two diseases is not definitely known, and its source cannot be eradicated.

In malignant tumors there has apparently been some slight benefit by transfusion. In cancer no beneficial result has been obtained in checking the growth, but in sarcoma or carcinoma where the disease is not too extensive, patients who are in poor condition or who have lost much blood, as from uterine hemorrhages, may by transfusion be made much better surgical risks. In tuberculosis there sometimes seems to be some benefit, but in surgical tuberculosis transfusion should be advised only to improve an operable risk. In chronic suppuration or in sepsis where no distinct septicemia or pyemia exists, transfusion often produces brilliant results. In shock and collapse it is a most valuable remedy. In hemorrhage, particularly when the blood is not pathologic, transfusion is practically a specific and should always be used when the loss of blood is so great as to make it probable that mere increase in the volume of blood as by normal salt solution or by Ringer's or Locke's solution, would not be adequate and would not

3 Hemorrhage and Transfusion.

leave enough corpuscles to carry on the vital functions. After poisoning from illuminating gas transfusion, particularly when preceded by free bleeding, should be tried if the patient has not responded to the usual remedies. Exophthalmic goiter is not materially benefited by transfusion. The shock and excitement may be distinctly injurious. In pellagra the reported results differ. Some authors advise transfusion, but the outcome seems to be uncertain. In pathologic hemorrhage, as hemophilia or purpura, or in hemorrhage accompanying jaundice, transfusion is distinctly indicated and is often beneficial and even life saving. The pathology of the blood in these conditions, however, has not been worked out and it is not fully known how the transfusion acts. In hemorrhage from the newborn, which is supposed to be caused by some defect in the capillaries, most brilliant results have been obtained. In hemophilia and in hemorrhage following jaundice good results and sometimes cures have been observed when other remedies had failed. Transfusion for puerperal convulsions has been tried, but is of doubtful value, whereas frequently the ordinary remedies are followed by cure.

According to Raulston and Woodyatt,[4] transfusion of blood in diabetes mellitus gives unsatisfactory and even injurious results.

The author's personal experience embraces transfusion in twenty-two cases. All were done by suture except the first in which the Crile cannula was used. Among the first series were some unsatisfactory results from a mechanical standpoint, which were largely due to the selection of too small a vein and to inexperience. In the cases of pellagra the disease was far advanced and the

4 Journal A. M. A., March 28, 1914.

veins were thickened. It was difficult to get a satisfactory flow into the vein. This was probably partly due to the terminal pathology from the disease. In other instances the transfusion technically has been satisfactory, and in all recent cases there has been no difficulty in introducing by this method as much blood as was thought desirable. Four transfusions were done for pellagra in three patients. In no instance was there any permanent beneficial result. Two transfusions were for sepsis. In one case, a large perforated gastric ulcer with general peritonitis, the patient was transfused, the ulcer closed and the abdomen drained. His condition was fairly good after the transfusion and after the operation, but he succumbed to the peritonitis within forty-eight hours. It was a late case, the perforation having existed probably for several days. In another case of sepsis, following injury to the knee with suppuration in the femur and thigh and profound sepsis, transfusion was done after amputation when the patient was practically pulseless. His pulse improved at once and though he had a stormy convalescence from sepsis, he eventually recovered. His recovery would hardly have been possible without the transfusion. In three cases of hemorrhage from the uterus, transfusion was done and was followed immediately by thorough curettage in one case and hysterectomy in two. They all recovered. In a case of placenta previa, the patient had lost an enormous amount of blood, the pulse at the wrist was barely perceptible, 160, and irregular. She was transfused and the condition was entirely altered. After the blood flowed fifteen minutes, the pulse came down and normal color returned to her face. Cæsarean section was immediately performed. The abdominal wound healed satisfactorily,

but there was sepsis in the uterus. She made a slow but complete recovery. In a gastric hemorrhage, the patient was a man about fifty years of age who had been bleeding at intervals for three days, vomiting large amounts of blood and passing black stools. His hemoglobin was down to twenty-five, and pulse rapid and weak. The patient was transfused and a quick gastroenterostomy was done immediately afterwards under ether. The pylorus was folded in. He made a prompt convalescence without any further bleeding. In a secondary anemia in an old man, there was marked improvement. This transfusion was done at the Mayo Clinic at the courteous request of Dr. Donald Balfour. About a month later Balfour wrote as follows: "He has improved wonderfully, the hemoglobin at the present time being seventy-five percent. However, there is more or less uncertainty about the ultimate outcome of the case, as there seem to be indications of the condition being due to carcinoma, probably of the body of the stomach."

One transfusion was for pathologic hemorrhage from hemophilia. The history of this case is fully given on page 173. There was temporary improvement, but no permanent benefit. One patient was transfused for pathologic hemorrhage from chronic jaundice without benefit except to improve the pulse for a day. The hemorrhage persisted and the patient died. A child four years old with secondary anemia following prolonged enterocolitis was transfused without permanent benefit.

To sum up, in anemia due to the loss of normal blood, transfusion gives brilliant results and is practically a specific. In secondary anemia from suppuration often excellent results can be obtained. When, however, the anemia is due to some toxic material in the blood or tissues, as in leukemia or pernicious anemia, transfusion

without removal of the source of the toxic material is of no avail and may even be injurious.

The following table shows the above cases classified:

SUMMARY OF TRANSFUSIONS.

Disease	No. of Transfusions	No. of Patients	Result
Pellagra	4.	3.	No benefit.
Uterine hemorrhage (hemoglobin 25 or under and general condition bad)	3.	3.	All recovered.
Ruptured uterus during parturition	1.	1.	Recovered from immediate effect. Died about 4 weeks later from cholecystitis and edema of lungs. No hemolysis.
Placenta previa	1.	1.	Recovery.
Sepsis (infected knee and thigh)	1.	1.	Recovery.
Sepsis (subdiaphragmatic abscess from neglected appendicitis)	1.	1.	No benefit.
Sepsis (large perforated gastric ulcer and general peritonitis)	1.	1.	No benefit.
Sepsis (large typhoid perforation and general peritonitis)	1.	1.	No benefit.
Hemorrhage (suicide, portal vein divided by pistol wound)	1.	1.	No benefit.
Hemorrhage (from throat, continuing a number of days; condition bad)	1.	1.	Recovery.

SUMMARY OF TRANSFUSIONS.—*Continued.*

Disease	No. of Transfusions	No. of Patients	Result
Hemorrhage (gastric ulcer, continuing at intervals for three days, hemoglobin below 25)	1.	1.	Recovery.
Noma of face (progressing rapidly)	1.	1.	No benefit.
Chronic entero-colitis (boy, aged 4 years)	1.	1.	No benefit.
Illuminating gas poisoning	1.	1.	No benefit.
Pathologic hemorrhage (jaundice)	1.	1.	No benefit.
Pathologic hemorrhage (hemophilia)	1.	1.	Temporary benefit, later death from recurrence.
Secondary anemia (probably cancer of body of stomach)	1.	1.	Temporary benefit.

None of these transfusions were done except as a last resort. Of the twenty-two transfusions on twenty-one patients, no benefit resulted in eleven patients, temporary benefit in three cases, and recovery in seven patients. When it is considered that all were desperate cases that in the best judgment of the operator would have died without transfusion the complete recovery of one-third of the patients (seven) with temporary benefit in three others is gratifying.

CHAPTER VIII.

HEMORRHAGE.

Hemorrhage is one of the most important features of surgical practice and in some form is met in every branch of medicine. A thorough comprehension of the causes of hemorrhage and the methods of treating it is necessary for both the surgeon and the general practitioner. Bleeding may be divided into hemorrhage resulting from a local lesion of a blood-vessel when the blood itself is normal; and pathologic hemorrhage, where the chief, if not the only, cause is some alteration of the blood, or a constitutional disease of the capillaries. The first may be subdivided into hemorrhage from direct trauma and that due to a local lesion of the vessel from disease, such as hemorrhage from ulcer of the stomach, or ulcer of the bowel. Hemorrhage under either of these heads is treated along the same lines, but in pathologic hemorrhage different problems arise.

The symptoms of hemorrhage are either obvious from the flowing of blood externally, or the blood may be concealed in one of the large body cavities or in the tissues. Diagnosis of concealed hemorrhage often presents considerable difficulty, particularly if it is accompanied by a trauma that may at the same time be a cause of shock. In both concealed hemorrhage and in shock the general symptoms are practically the same. Concealed hemorrhage may be quite extensive before any symptoms are manifested. Hemorrhage in special areas, as in the brain, may cause serious symptoms and even death, due,

not to the amount of blood lost, but to the location of the clot. Symptoms from hemorrhage resemble those of shock so closely because in each instance the vascular system is suffering from a lack of blood. In hemorrhage it has gone outside of the vascular system, whereas in shock the great dilatation of the internal blood-vessels makes the space larger than the blood can fill. The symptoms also depend upon whether the blood is lost suddenly, for a small amount bled quickly will produce more disturbance than a larger quantity if gradually lost. Frequently the patient faints in external hemorrhage solely from psychic causes. The blood pressure falls rapidly in marked bleeding. The patient is usually anxious, prostration begins, the hands and feet are cold, and the surface is chilled and clammy. The skin becomes pale or even bluish, and the pulse is quickened. The temperature falls steadily and soon is subnormal, even if the patient has fever. Breathing is short, sighing and distressed. Cold sweat appears on the forehead, chest, and the palms of the hands. Frequently the patient yawns and becomes restless. Thirst is a prominent feature. If the patient attempts to sit up he often falls back in syncope, which is not psychic, but due to lowered blood pressure. As the hemorrhage increases the pulse becomes irregular and respirations are shallow. The skin assumes a waxy hue, the pupils dilate, and the mouth tends to gape. There is often muscular twitching. The patient may become unconscious, or may complain of vertigo. There may be nausea and vomiting. Roaring sounds are sometimes heard in the ears. Dark specks or flashes of light may be seen. The sphincters are relaxed.

Often it is necessary to differentiate between internal hemorrhage, as in the abdominal cavity, and shock. While the symptoms naturally are not unlike, there are

certain distinguishing features that may aid in a diagnosis. The history of the case is important, particularly as to whether the injury would be more likely to cause hemorrhage or shock. An injury from a bullet or stab wound would be more apt to cause hemorrhage than shock, whereas a crushing injury might cause hemorrhage, but would probably produce shock.

According to Crile, two facts stand out clearly in the clinical differentiation between shock and hemorrhage. The first is that there is usually a primary state of excitement in hemorrhage, which is absent, as a rule, in shock; and, secondly, the pulse rate in hemorrhage is always increased, whereas in shock it is usually increased, but may be decreased in frequency. One of the most important means of differentiating between shock and hemorrhage is by examination of the blood. According to Crile, when hemorrhage occurs, blood examinations will show a fall in the number of red cells, a decrease in the hemoglobin, and an increase in the white cells. The maximum increase occurs early. In shock, however, there is no fall in the hemoglobin, or in the red cells and no increase in the white cells. The observations of Crile on patients who had acted as donors in transfusion tallies very closely with his experiments on lower animals, so the findings of a blood analysis in the differentiation between shock and hemorrhage may be regarded as based on both clinical and experimental observations.

Treatment.

Treatment of hemorrhage due either to a trauma of the vessel by mechanical force or to a lesion produced by local disease is identical. Treatment may be either local or general, and frequently measures have to be adopted with considerable nicety of judgment. For instance, one

of the general phenomena of hemorrhage is the lowering of blood pressure. This may be taken as nature's method to promote clotting and stop the hemorrhage. If stimulants are administered too vigorously, either in the form of drugs that raise the blood tension, or by filling up the vascular system, as with salt solution, the hemorrhage may actually be made worse. On the other hand, if the blood pressure is permitted to fall too low, the patient may die from syncope.

The method of decreasing the blood pressure to the region that is bleeding, provided it does not involve vital centers, has the advantage of checking the hemorrhage without the disadvantage that would accrue to a low blood pressure in a vital part. If the hemorrhage results from a small wound, efforts should be made to control the bleeding point directly. When the bleeding comes from a large vessel in a small wound, pressure with the fingers on the injured vessel will stop the hemorrhage. A. P. Gerster reports a case in which a butcher accidentally wounded his femoral artery with a sharp knife. Gerster happened to be present and immediately inserted his finger into the wound, thereby controlling the bleeding until the patient could be anesthetized and the artery tied. While it is desirable to use as much asepsis and cleanliness as possible, in injuries of large vessels death will soon occur unless the hemorrhage is promptly checked and time cannot be lost for any other consideration. If bleeding is not severe, other measures can be adopted. One of the most important therapeutic agents is changing the position of the bleeding part. If bleeding comes from the head, the head should be elevated and if from the arm or leg the affected limb is raised. This very materially decreases hemorrhage. Flexion of the

arm or leg in addition to elevation will reduce the local blood pressure still more.

Pressure is one of the most effective methods of dealing with hemorrhage. Pressure can be applied directly or indirectly. Direct pressure upon the bleeding part is very effective. It is often better than the blind application of a clamp.

W. J. Mayo speaks of several instances in which the renal artery retracted from the pedicle after nephrectomy, or was injured during operation, and he promptly controlled the hemorrhage by grasping the artery with his fingers. In such a large vessel, pulsations can be easily felt and, as Mayo says, the artery "fairly jumps into the fingers," whereas the blind application of forceps in a bloody field may do great damage. After the vessel has been caught in the fingers forceps are accurately applied.

Indirect pressure to control hemorrhage may consist either of direct pressure over the main trunk of the artery that leads to the bleeding point, or a constriction of the whole limb by a tourniquet. Indirect pressure is best made in emergency by the intelligent application of the hand or fingers. Occasionally a strong truss pad might suffice. The method of controlling the larger arteries by simple pressure with the fingers is shown in the accompanying illustrations. (Figs. 58, 59, 60, and 61.) Even the abdominal aorta may, according to McEwen's method, be compressed and if the circulation is not entirely stopped often the blood pressure is so lowered that a clot may form. It must be remembered that the character of the blood rapidly changes after hemorrhage and the disintegration of the platelets. Unless the hemorrhage is pathologic, clotting will take place more readily after

bleeding has already occurred, provided some assistance is given nature.

A tourniquet is most valuable in controlling hemorrhage in the extremities. The tourniquet now usually employed is an elastic rubber band or tube. Before applying it the leg or arm should be elevated and the typical Esmarch bandage may be used before tightening the tourniquet.

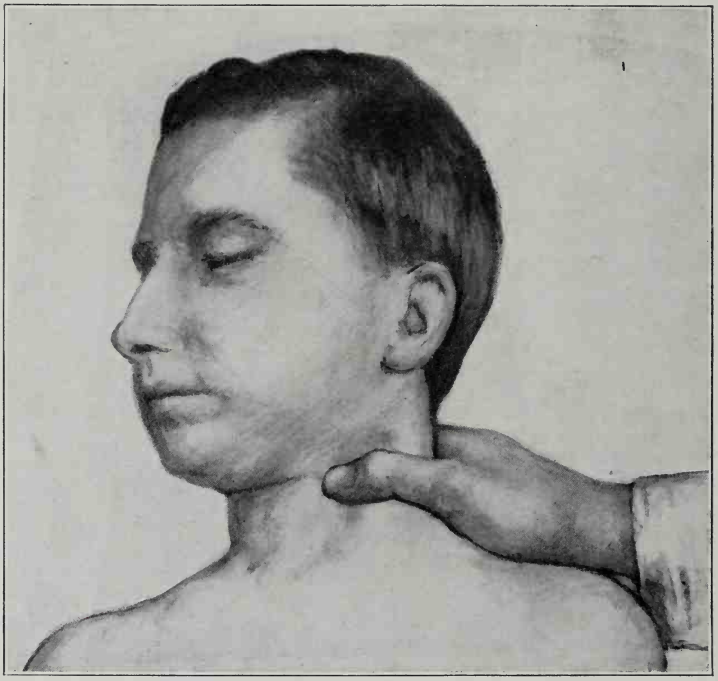

Fig. 58.—Digital compression of carotid artery. (Marwedel.)

The tourniquet should not be too near a joint, but preferably on the muscular part of the thigh or arm. It must be tightened quickly because if first loosely applied, it will merely constrict the venous circulation and produce a venous hyperemia, whereas if quickly tightened both the venous and the arterial blood will be cut off at the same time. A tourniquet should not, as a rule, be left

on much more than an hour. If it remains on longer than an hour in elderly people with bad arteries, there may be gangrene of the limb, though in younger persons it can be kept on several hours if necessary. Frequently the unskillful application of a tourniquet may result disastrously and by not being tight enough it may cause more bleeding than if no tourniquet at all had been used.

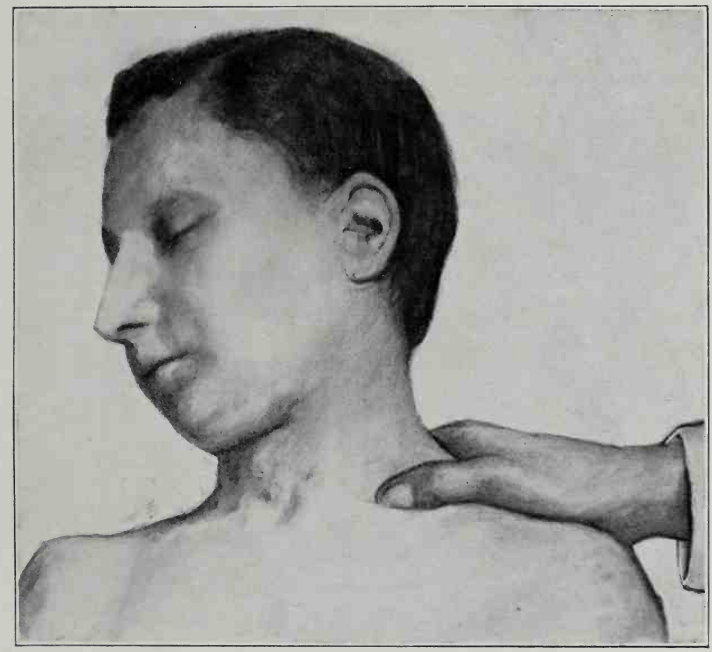

Fig. 59.—Digital compression of subclavian artery. (Marwedel.)

Momburg even places a tourniquet around the abdomen to constrict the abdominal aorta. The waist of the patient is encircled by a heavy rubber tube midway between the crest of the ileum and the costal arch. The tube should be one-half inch in diameter and very elastic and should be wound around the trunk several times until pulsations in the femoral are arrested. This should not

be done until the patient is completely relaxed under a general anesthetic. The Esmarch bandage had best be placed on the legs just before using this tourniquet. The bowels should be well emptied before the operation and the tourniquet should be put on with the patient in the Trendelenburg position so the intestines will not be too greatly constricted. This method has been advised

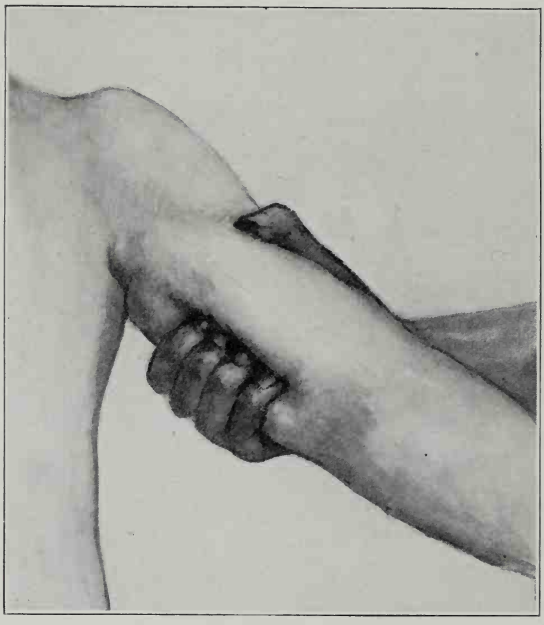

Fig. 60.—Compression of brachial artery. (Marwedel.)

in hemorrhage from the uterus and may be used in an emergency, though it is by no means free from danger.

Often the gradual binding of the entire limb from the distal extremity toward the trunk will modify hemorrhage. This, of course, is quite different from a loosely applied tourniquet, as the compression extends over the whole of the limb and it is not possible to produce venous

hyperemia in this way. To show how effective it is in combination with elevation, John A. Wyeth, of New York, often amputates the lower part of the foot or ankle, sutures the flap, but does not tie the vessels, relying upon the elevated position and the firm application of a bandage over an abundant amount of cotton which will

Fig. 61.—Compression of femoral artery. (Marwedel.)

produce elastic and uniform pressure from the stump to above the knee.

Pressure can also be applied by a tampon. The tampon should consist of strips of sterile or antiseptic gauze that are systematically packed firmly to fit every irregularity of the wound. The form recommended by Mikulicz is the best in a large wound. Here one or two

layers of gauze are spread over the wound and strips are packed on the gauze. In this manner the packing can be readily removed and the pressure is somewhat more equally distributed.

Heat is one of the most satisfactory local remedies in hemorrhage. It may be applied in the form of hot water or metal heated as the Paquelin cautery, or as the plumber's soldering iron, or by electricity, as the electric cautery.

Downes devised a clamp containing an electric cautery which is used by several surgeons instead of ligatures. The heat of the cautery should not be too great if the effort is solely to control hemorrhage, else the vessels may be cut through as with a knife. If very hot water is used its action should be limited to a local area; otherwise its temperature should not exceed 120°. Above this point damage is readily done to the tissue. Water at 115° will usually control ordinary bleeding from small points. If the action of boiling water can be limited, as by wringing cloths out of boiling water and applying for a few minutes to a small wound, generally no damage results. A temperature of 115° to 120° can be maintained for some time without any serious injury to the tissues. Occasionally, as in bleeding from the uterus, when even hot water does not control, the injection of a spray of steam will stop the bleeding. Extensive sloughing may follow this procedure and it should not be used unless no other measure seems effective. It is particularly suitable in the uterus, as steam may be introduced into the uterine cavity through a tube that contains a number of openings. It is called "atmokausis."

Cold occasionally makes a satisfactory hemostatic agent. It is not so good as heat and tends to depress the vitality of the tissues if long maintained. Cold also re-

tards coagulation. It is of service in certain instances, as in hemorrhage of the gums. Where considerable bleeding is expected, freezing the sockets of the tooth and the gum with a spray of ethyl-chloride is often effective when the hemorrhage would otherwise be very troublesome. This procedure has been particularly recommended in extracting a tooth in one who is probably hemophilic. The application of gelatin has been advised by some, but it is of doubtful value.

Bleeding from bone may be checked by the application of Horsley's wax, a preparation devised by Sir Victor Horsley. It consists of beeswax seven parts, almond oil one part, and salicylic acid one part. The mixture is firmly pressed into the surfaces of the bleeding bone. The wax is antiseptic and is well borne by the tissues. It acts by filling up the cavities in which the bleeding vessels lie. Another very effective method is the application of a bit of muscle. If hemorrhage from an injured skull cannot be controlled otherwise, a piece of muscle can be cut from the temporal muscle and pressed upon the bleeding spot. In the brain a small piece of muscle laid on the bleeding area often stops the hemorrhage promptly. It is probable that muscular tissue contains a considerable amount of thrombokinase, which hastens clotting.

The treatment of traumatic hemorrhage by other than local measures consists in the administration of such drugs or remedies as may tend to keep up the blood pressure if it seems to be falling to an alarming extent. Suprarenal extract contracts the peripheral vessels and raises the blood pressure. It is, however, a dangerous drug unless carefully used and should be administered cautiously and in small doses. Its action is evanescent. Bandaging the extremities drives more blood to the vital

centers and increases blood pressure. Morphine is one of the most satisfactory heart stimulants and at the same time quiets the restless patient. Strychnine and digitalis are recommended by many authors.

Hypodermoclysis in hemorrhage is valuable. Normal salt solution, nine-tenths of one percent sodium chloride, or Ringer's or Locke's solution may be used. Gravity is the most satisfactory method of introducing it. The skin should not be permitted to become tense, as necrosis may occur. Where haste is not too important, hypodermoclysis will often be most beneficial and may be given in several portions of the body at the same time. The skin can be readily sterilized by tincture of iodine and a sterile aspirating needle introduced well beneath the skin or under the mammary gland. The needle should be held in place by antiseptic adhesive plaster.

The use of intravenous infusion sometimes gives prompt results when the case is urgent. A blunt intravenous needle with a glass irrigator and connecting tube are sterilized. The vein selected should be near the elbow and is rendered prominent by slight pressure upon the arm, or by cording the arm sufficiently to bring out the vein. The skin is cleaned and infiltrated with novocaine or a weak solution of cocaine. The skin over the vein is caught with thumb forceps, lifted up, and with sharp scissors the portion of the skin in the grasp of the forceps is cut off. This leaves an oval wound which fully exposes the vein. It is impossible to wound the vein or lift it up in this manner. A few strokes of the knife or the scissors then readily frees the vein. It is ligated below, and part of its wall just above the ligature caught with a mosquito forceps. With sharp scissors an oblique cut is made about one-half way through the caliber of the vein, and the intravenous needle is introduced with

the solution flowing. If the needle is not available, a medicine-dropper will serve every purpose.

According to Crile, most pathologists at large hospitals point to cases where intravenous infusion has been used without benefit and which show, on post-mortem examination, edema of many organs with free fluid in the body cavities. Not more than three or four pints of solution should be used, usually one-half of that quantity is all that is necessary. A larger amount tends to embarrass the heart, and may cause dilatation of the heart, or else rapidly leaves the vessels, passing into the tissues or into the bowel, or through the kidneys. About three cubic centimeters per minute is sufficient, and never more than a quart should be given in fifteen minutes. Where marked shock accompanies the hemorrhage, injection of suprarenal extract into the salt solution raises the blood pressure quickly. It may be mixed with the saline solution or injected in a stronger solution from a hypodermic syringe, the needle of which is thrust into the rubber tube of the irrigator. At the slightest evidence of dilatation of the heart the patient should be put in as near a vertical position as possible and massage made over the heart. The best solution for intravenous use is either normal salt solution, nine-tenths of one percent, preferably made of distilled water, and, of course, sterilized, or Ringer's or Locke's solution. The formula for Ringer's solution is sodium chloride, 0.7 percent; potassium chloride, 0.03 percent; calcium chloride, 0.025 percent in distilled water. Locke's solution, which is by some considered better, consists of sodium chloride, 0.9 percent; calcium chloride, 0.024 percent; potassium chloride, 0.042 percent; sodium bicarbonate, 0.01 to 0.03 percent; glucose, 0.1 percent in distilled water. These solutions are introduced at a temperature between 115° and

120° as the effect of the heat upon the heart is very stimulating.

Transfusion of blood is indicated in any case of hemorrhage in which the hemoglobin is so low that it is doubtful whether enough corpuscles are left to perform the vital function of carrying oxygen. Crile has pointed out that in shock, after severe hemorrhage, and in certain other conditions where it was formerly thought no pathology could be found, a careful examination of the brain shows destruction of the cortical cells. If the hemorrhage is severe or if the anemia is prolonged many of these cells are permanently injured. So, even if a patient barely escapes with his life after a severe hemorrhage, there may be such permanent damage to the cortical cells of the brain as to make it impossible for him ever to recover fully. Many so-called neurasthenics may be explained in this way. It has been shown that a dog can be killed by strangulation and resuscitated by injection of normal salt solution with a small amount of suprarenal extract into an artery, the injection being directed toward the heart. Pressure thus induced in the coronary arteries will sometimes start the heart, even after the dog has been dead seven minutes. The animal, however, does not live long if he is resuscitated after seven minutes. After being dead only one or two minutes the animal may survive indefinitely. An interesting point is that after the longer periods resuscitation is followed by very incomplete function. The dog is blind and deaf and cannot use any of the higher senses. A shorter period is followed by retention of only some of the special senses, and a still shorter period will probably result in the loss merely of certain recently acquired tricks that the dog formerly knew. In other words, it seems that a nonfatal anemia of the brain,

whether partial or complete, extending over a considerable period of time, may cause degeneration of an abnormal amount of cortical cells, with resulting symptoms such as loss of memory, inability to collect thoughts, groundless fears, etc.

Aside from the treatment that has been outlined, the usual efforts for maintaining vital energy are employed as in shock. Cold should never be used to stop bleeding when the general vitality of the patient is low.

The hemorrhage that occurs during surgical operations may be considered in separate detail. One of the most important things is prophylaxis. Careful hemostasis, stopping each bleeding point and operating in a dry field, is the ideal. Sometimes this ideal cannot be attained. Where hemorrhage is unavoidable, as in the separation of massive adhesions, it is best to proceed as quickly as possible so the bleeding surface may be exposed and subjected to the pressure of gauze. In dealing with hemorrhage in operations, we must consider not only the immediate bleeding that occurs during the operation, but what occurs subsequent to operation, which is often just as important. In the extremities a bloodless field can be maintained by the application of a tourniquet. A tourniquet is followed by oozing and often the amount of blood that escapes after operation is considerable. When a dissection on an extremity necessitates a perfectly dry field a tourniquet should be used, the limb being first elevated or the Esmarch bandage applied from the extremity of the limb toward the body, and then an elastic tourniquet is quickly adjusted. For ordinary purposes, however, it is frequently best to dispense with the tourniquet and carefully check the bleeding as it occurs by seizing the small vessels with hemostats and ligating the large vessels before dividing them. After an operation

of this nature there is practically no after oozing, and the vitality of the tissues is not affected by depriving them of the circulation of the blood as is the case when the tourniquet is used. Undoubtedly, the application of a tourniquet has been much abused. Maintaining the resistance of the tissues by gentleness and careful hemostasis and by preserving the circulation of the blood, is almost as important in preventing infection as careful asepsis. Too much delay and indiscriminate clamping, on the other hand, create trauma, which is often unnecessary and always undesirable. The operator should try to control bleeding without excessive injury to the tissues, and at the same time without delaying the operative procedure unduly. In patients whose vitality is very low, as in sufferers from extensive tuberculosis of the bone, the application of a tourniquet is unwise. These individuals are emaciated and stand trauma badly. Their tissues also have little resistance. A tourniquet here produces considerable shock and the pressure on the muscles, blood-vessels, and nerves causes additional trauma, and is followed by marked oozing. Depriving the tissues of blood by a tourniquet during the operation also lowers their resistance. The author has on two occasions amputated the hip joint without a tourniquet, by the dissecting method, clamping or tying the large vessels in the course of the incision before they were cut. It is surprising how much less shock there is and how much more promptly the tissues healed under such treatment than after the application of a tourniquet.

In operations about the head and neck, posture is an excellent means of lessening hemorrhage. The sequestration anemia of Dawbarn, is also of service here. He applies a tourniquet on all the extremities close to the body just tightly enough partially to obstruct the venous

return, but not to occlude the arteries. Thus passive congestion of all the extremities is produced and blood is stored up. The blood pressure is, consequently, lowered and there is much less bleeding in the operative field. The head and neck should be elevated. Care must be taken, however, to prevent syncope which may follow if a too erect position is maintained and particularly if chloroform is the anesthetic.

The operator should learn that he can control any hemorrhage in the vast majority of instances if he will keep cool and use common sense. In such accidents as the retraction of the renal artery from its pedicle the artery can be felt and grasped with the fingers. In a sudden hemorrhage, which usually comes from one point, the fingers are the best temporary means of controlling the bleeding. If it is a venous hemorrhage, packing should be used and firm pressure. The packing is removed a little at a time until the bleeding points are isolated and clamped. Tampons for the permanent control of hemorrhage should rarely be employed, particularly if the bleeding is arterial.

In hemorrhage during operations upon the bladder, hot water is useful. Sometimes, when a wide exposure has been made the bleeding point may be seen and sutured, but generally bleeding from the bladder can be controlled temporarily by firm pressure with dry gauze or with gauze wrung out of very hot water until irrigation is begun. The irrigation consists of a constant inflow of water at a temperature at about 115° F. through a catheter in the penis in suprapubic operations. The outflow is provided for by a larger tube in the wound, which can also carry off small clots. This may run from twelve to forty-eight hours and is discontinued when the return flow is entirely clear for several hours. The

hemorrhage is not only controlled but the irrigation of warm water seems to have a beneficial effect upon the secretion of urine (page 163).

The local application of drugs such as suprarenal preparations, gelatin, antipyrin, and the iron salts in Monsel's solution is but seldom indicated in ordinary hemorrhage. Compound alum powder (Squibb's surgical powder) may sometimes be employed as it is antiseptic. A small gauze bag may be filled with this powder and put in the wound. In most operations, however, such remedies are hardly justifiable.

Treatment of Special Hemorrhage.

Hemorrhages often require remedies that are peculiarly suited to the regions from which the bleeding comes. These regions may be divided into the head, neck, extremities, chest, and abdomen.

Hemorrhage from wounds of the scalp is very common. The anatomy of the scalp renders it difficult to clamp and ligate the individual vessels. The bleeding can be satisfactorily controlled by passing a suture under the vessel. This is done while the wound is being closed. Care should be taken to tie the ligature just tight enough to stop the bleeding, as too great constriction may result not only in necrosis but in secondary hemorrhage. With a sharp needle and iodized catgut bleeding from the scalp may be quickly controlled. A continuous button-hole stitch should be used, carefully adjusting the tension on each stitch. When the bleeding is from bone, pressure with a gauze sponge may check it. If it does not, the bone can sometimes be crushed with heavy forceps. One of the most satisfactory remedies is to cut a piece of muscle from the nearby tissue, usually from the temporal muscle, and rub it firmly into the bleeding spot. The

wax of Sir Victor Horsley may be used (see page 145). If the bleeding comes from the dura, it is controlled by sutures of fine silk or catgut. Bleeding from the surface of the brain, if profuse, may be stopped by passing fine catgut in a small needle under the bleeding vessels. The ligature is tied with just enough tension to check the bleeding. If a large vessel is not involved the application of a small bit of muscle tissue may suffice. The general rule of dealing as gently as possible with brain tissue and never touching it unnecessarily should always be remembered. Some surgeons advocate constant irrigation of the surface of the brain during operation with salt solution or even with an antiseptic. Bleeding should be controlled without leaving any packing or gauze on the cortex of the brain.

Bleeding from the face, if not very profuse, can usually be stopped by pressure. The arteries of the face are so richly supplied with muscle and are so ready to respond to dilatation or contraction, that they contract powerfully and under a comparatively slight stimulant. A hemostat left on a large artery of the face for a few minutes will often occlude it. However, it is best to ligate a vessel of importance by passing a suture underneath it. Here, as elsewhere, catgut is the most desirable material. Bleeding from the nose ordinarily ceases without trouble but sometimes demands the best resources of the surgeon. Occasionally, in recurrent hemorrhage from the nose, the bleeding spot can be located on the septum from a branch of the artery to the septum. The spot should be touched with the point of a fine electric cautery or a small piece of chromic acid on a probe may be rubbed into it. If the bleeding is from farther back in the nose and it is impossible to locate the spot, the head should be raised and the patient kept quiet

with an ice bag placed to the head or neck. This produces a reflex contraction of the smaller arteries and will often control the hemorrhage. The old-fashioned practice of dropping a bunch of cold keys down the back of the neck has a scientific basis. If the bleeding still persists, the posterior nares should be packed. This can be readily done by passing a small soft rubber catheter along the floor of the nose until it appears in the pharynx. The catheter is then seized with forceps through the mouth and drawn out. A mass of gauze is tied to its end and shoved well into the pharynx and up into the posterior nares. The catheter is then pulled on, which maintains the tension. In profuse bleeding it may be well to attach two stout cords to the catheter and draw them through the nose. The gauze is then tied on the cords, pulled up into the posterior nares, and a plug of gauze fitted into the anterior nares and held in position by tying the cords together over it. A large rubber finger cot or a small rubber glove may be carried on a probe along the floor of the nares and inflated to produce pressure. A finger cot may be tied over the end of the catheter if the bleeding area can be reached this way, inserted opposite the bleeding spot, and then blown tense through the catheter. Sometimes the nose is tamponed with strips of gauze. In hemophiliacs, when the blood clots slowly, tampons are very unsatisfactory. Various solutions have been used but probably the best is the application of peroxide of hydrogen by means of an atomizer, repeated at frequent intervals, spraying only a small amount at a time. It is said to be a most efficient means of controlling nasal hemorrhage. Suprarenal extract if strong enough to control the bleeding, may be dangerous, partly from the constitutional effect, but largely because a secondary relaxation often sets in, the vessels

being paralyzed from the intense contraction, and bleeding may be even more difficult to check than it was at first. Sometimes it is even necessary to ligate the external carotids in the neck.

Bleeding from the mouth is usually serious only in cases of hemophilia, though in an angioma of the mouth it is often profuse. If there is a persistent oozing, freezing the tissues with ethyl-chloride may stop it. Too much of this drug should not be used as it is a very strong general anesthetic, and the surplus should be caught on gauze packed around the bleeding surface. Packing the cavity full of gauze or, in an emergency, using a clean handkerchief, and having the patient shut his mouth firmly on the packing will control most hemorrhages along the alveolar process, even if very severe.

Hemorrhage from the tongue is controlled by a suture placed through the tongue just posterior to the bleeding surface, or the bleeding surface if small may be sutured. Bleeding from the tonsils is often obstinate, especially after the radical operation for excision. Washing out the throat thoroughly by gargling with very hot water, or with ice water, and pressure on the bleeding area with dry gauze is usually sufficient to check the bleeding. Special instruments are devised by which continuous pressure is exerted by means of a forceps holding gauze in one arm which is inserted into the throat, the other arm being placed externally. The pressure is regulated by a catch or screw, or by an elastic band. If bleeding is not checked in this way the external carotid should be ligated, care being taken to include the ascending pharangeal, which comes from the external carotid near its origin.

Bleeding from the neck requires no special measures except care to avoid entrance of air into the veins. This

is peculiarly liable to happen in the internal jugular and the large veins in the root of the neck. Arterial hemorrhage may often be checked by posture, elevating the head and neck, and by putting a tourniquet on the arms and legs near the trunk to obstruct the venous circulation, but not the arterial—the so-called "sequestration anemia" mentioned above. The patient should be carefully watched to prevent the blood pressure becoming too low. In a stab of the neck where the wound is small, the finger should be inserted to control the bleeding spot. If it cannot be controlled in this way, gauze, or a clean handkerchief in an emergency, is packed in and pressure maintained until the wound is enlarged, and the bleeding point identified and properly closed. In operations on the neck, hemorrhage should be carefully controlled by ligature or suture before the wound is sutured, as the strain of vomiting or coughing after an anesthetic raises the blood pressure, particularly in the neck, and the movements of the head may accelerate bleeding.

Hemorrhage from the chest if superficial is treated on the general principles already outlined. Usually the bleeding point can be clamped and ligated. If the hemorrhage is from the heart, the heart should be sutured according to the methods described in surgical works on this subject. Hemorrhage from the intercostal arteries is often severe. The lower intercostal artery hugs the rib closely. In resection of the rib, if the periosteum is stripped off, the artery will not be injured. In compound fracture of the rib, the hemorrhage may be quickly controlled by passing a catgut ligature around the rib a short distance from its end, taking care to include considerable soft tissue in the suture. This can be tied firmly and will occlude the intercostal vessels. Bleeding

from the lung is controlled by packing and by letting air into the pleural cavity through a drainage tube. This causes collapse of the lung and consequent contraction of the bleeding spots. The great danger in such instances is the possibility of infection of the pleural cavity.

In the abdomen, the chief sources of hemorrhage are the stomach, intestines, kidneys, bladder, liver, spleen, and uterus. The liver on account of its size and the spleen on account of its structure are frequently injured and control of the bleeding may be difficult. The bleeding area should be sutured with heavy catgut on a blunt needle or probe and the sutures tied gently. If suturing is impossible, gauze packing should be used. Hemorrhage from the stomach may be due to a passive hyperemia from affections of the liver such as cirrhosis, an ulcer, a tumor, or an inflammatory mass which presses upon the veins. Affections of the spleen, such as splenomegaly, which produces great hyperemia in the neighborhood of the spleen and in the liver, also cause bleeding from the stomach. Such hemorrhages are treated by emptying the stomach and often by gastric lavage, using hot water to which a small amount of soda has been added. A frequent cause of hemorrhage of the stomach is gastric or duodenal ulcer.

Hemorrhage from gastric ulcer is always a serious matter. The authorities estimate that from three to six percent of all patients having gastric or duodenal ulcer die from hemorrhage. Thus, von Mikulicz [1] says that in gastric ulcer "Leube observed hemorrhage in forty-six percent of his cases. Müller says it was present in 120 cases which came to autopsy, it being the cause of death

[1] Von Bergmann and Bull: System of Practical Surgery, Vol. IV, page 304.

in fourteen of these cases. Welch estimates that from three to five percent of patients having gastric ulcer die from hemorrhage."

Thompson, professor of surgery in the University of Texas, describes two cases of duodenal ulcer in his own practice that died from hemorrhage.[2] In referring to the literature he says Moynihan reports that "in his second series of cases (101) hemorrhage occurred in forty-nine (almost fifty percent)." He also says, "Perry and Shaw estimated that thirteen percent of the bleeding cases end fatally." Moynihan [3] divides these cases into four classes. In the first, the hemorrhage is trivial and often inconspicuous. In the second, it is somewhat more severe. In the third group, the hemorrhage occurs after an exacerbation of other symptoms. In chronic cases it is repeated and abundant. "Its persistence and excess cause grave peril and will, if unchecked, be the determining cause of the patient's death." In the fourth group the hemorrhage is overwhelming and lethal. Observable hemorrhage occurs in about fifty percent of all cases of gastric or duodenal ulcer and about one-tenth of these die solely from hemorrhage.

The treatment of this complication, then, is of great importance. In acute cases, the hemorrhage will usually stop under medical treatment, and it is important to recognize acute cases. They occur, as a rule, in young adults and are preceded by symptoms for only a few days or a few weeks at most. The chief symptom is pain, referred to a point between the ensiform cartilage and the navel. If the stomach is emptied and kept at rest for several weeks, acute cases usually do not suffer from recurrent hemorrhage. The chronic cases may oc-

2 Transactions of Southern Surgical and Gynecological Association, Vol. XXV. page 249.

3 Abdominal Operations, page 160.

cur either in young adults, or in the middle aged or old. They have a history of indigestion for months or years, and suffer from "nervous dyspepsia" relieved sometimes by soda or food. Here hemorrhage is most dangerous. It is this type that belongs to the third and fourth groups of Moynihan.

The treatment consists in giving the stomach absolute rest by withholding both food and water and in nourishing the patient per rectum. Duodenal feeding through a small tube may be practiced after the acute danger of hemorrhage is over and when the rectum begins to be intolerant. The principles of treatment are the same as in incomplete abortion. The uterus is emptied in the latter instance to permit the contraction of its walls, thus closing the vessels. Keeping the stomach empty does the same thing. If bleeding persists or recurs, particularly in chronic cases, operation should be done. The pylorus should be folded in on itself with sutures and a posterior gastro-enterostomy by the no-loop method performed. The folding in of the pylorus usually produces some pressure upon the ulcer and the gastro-enterostomy drains the stomach and keeps it collapsed. If the hemorrhage is large in quantity, persistent, and recurrent, particularly in the middle aged, and if the patient seems too anemic to stand an immediate operation, transfusion of blood should be done, followed immediately by gastro-enterostomy and closure of the pylorus. Here transfusion renders operation comparatively safe. With the waiting method in such cases, as shown by the authorities quoted, death will often occur from hemorrhage or the resulting anemia may produce nervous and mental symptoms, as has been pointed out by Crile.

Hemorrhage from the bowel except from the rectum is difficult to control by direct applications. Bleeding

from typhoid ulcers if severe may possibly be subjected to operation, though only after other means of checking the hemorrhage have been tried. Prophylaxis in regard to the diet and rest of the intestinal tract should always be observed. If, however, the hemorrhage is persistent a laparotomy under local anesthesia would be justifiable. The hemorrhage probably comes from the lower two feet of the ileum, which is also a frequent site of perforation. The bleeding spot is controlled by excision of the ulcer and suturing the wound carefully with two layers of sutures. If well localized and small, it may be infolded with a purse-string suture, but with skilful suturing excision of the ulcer will probably be more satisfactory than attempting to infold a mass of diseased and thickened intestine. If the suturing is gently done under novocaine without too much pulling on the intestine or its mesentery, there will be surprisingly little shock, though any operation is a serious matter in the usually desperate condition of these patients.

Hemorrhage from the rectum should be controlled if possible by direct suture of the bleeding point, though if bleeding is chiefly venous, a tube wrapped with gauze and inserted in the rectum through a speculum will stop the hemorrhage. There should be enough gauze to produce considerable pressure; the tube allows the escape of gas. Hemorrhages from the liver from accidental wounds are controlled by sutures, which may be applied with special blunt needles, called liver needles, or by means of a probe which is easily passed through the liver tissue, or by passing a large needle eye first. The stitches are tied carefully because if too much tension is made they will cut through. Very stout catgut is the best material, and the stitches may be placed interruptedly or as a continuous mattress or a cobbler's

stitch. If a portion of the liver is resected, its raw surfaces should be brought together with sutures, which readily controls the bleeding.

Hemorrhage from the kidneys is sometimes exceedingly troublesome. It is often more indicative of a serious affection of the kidney than dangerous in itself. Malignant growths frequently bleed in the early stages. The so-called essential hemorrhage of the kidney, which is supposed to occur without organic lesion, is rapidly disappearing on finding, as a rule, organic lesions as a cause of most hemorrhages. Renal hemorrhage is usually caused by stone, malignant growths, tuberculosis, or nephritis, but there still remains a small group of so-called essential hemorrhages difficult to explain. In a few cases it is probable that enlarged veins about the calices are the source of the bleeding. Internal remedies are of doubtful advantage. H. H. Young has recommended catheterizing the ureters and irrigating the pelvis of the kidney with a weak solution of suprarenal extract. Internal administration of tincture of guaiac has been recommended, though its action, if it has any, appears to be empirical. Often incision through the capsule of the kidney, stripping the capsule, or an incision into the pelvis of the kidney seems to stop the bleeding. It is supposed that by this latter procedure dilated veins are broken and destroyed. Sometimes the hemorrhage demands a nephrectomy. Bleeding from injuries of the kidney is controlled by firm packing or by suture. Suture is by all means preferable when it can be used. Catgut is the best suture material and is inserted in round needles. The stitch should be interrupted and just tight enough to check the bleeding, for if too tight it will certainly cut through. Even profuse bleeding from the kidney is readily controlled by a few su-

tures tied gently. The mattress stitch, advocated by some, stops bleeding but injures a great deal of the kidney parenchyma, as all of the kidney substance within its grasp may be destroyed; whereas with a simple interrupted suture, the only tissue affected is in the direct plan of the stitch. Several experimenters have shown the advantage of the simple stitch in this connection, some of the best work along this line being done by James E. Moore and J. Frank Corbett, of Minneapolis.

Hemorrhage arising from the bladder is infrequent, for usually blood in the urine is from the kidneys or urethra. However, tumors of the bladder, particularly papillomas, or growths of the prostate may cause severe bleeding. When the prostate is enlarged and its veins engorged, the hemorrhage is often difficult to control unless the prostate itself which causes the engorgement is removed. Irrigating the bladder with hot water is one of the most satisfactory methods of checking bleeding from the bladder. In persistent hemorrhage from a papilloma, the growth itself should be removed either by operation or by electricity, using either the high frequency, or dessication, or the d'Arsonval current which is highly recommended for neoplasms of the bladder, even for malignant growths.

After wounds of the bladder, particularly after prostatectomy, control of hemorrhage is exceedingly important as the elderly patients on whom prostatectomy is done bear loss of blood poorly. Bleeding can be controlled after a suprapubic operation better than after the perineal method, for if packing is used it can be firmly pressed down on the wound, or if irrigation is relied upon the bladder can be kept full of hot fluid. In the perineal method the water must either return immediately through a larger tube or else must accumulate

under pressure, while packing frequently forces its way into the bladder and is not efficient. After the suprapubic operation several measures are advocated. Some surgeons, as Cabot, of Boston, make a wide incision into the bladder and suture the bleeding cavity with a continuous catgut stitch, paying particular attention to the posterior margin of the wound where it is claimed the arterial bleeding occurs. Others advocate firm packing of the cavity which is retained either by a catgut stitch or by leaving a pair of forceps to press upon the packing, having the handles of the forceps protrude from the wound and attached to a light elastic band across the dressing. Or the packing may be attached to a rubber catheter which has been introduced through the urethra and traction made on the catheter. If packing is left without some retentive apparatus, it does not remain in the cavity from which the prostate is removed and it may be necessary to fill the bladder with gauze. Packing is often accompanied by reflex disturbance of the kidneys, and tends to promote uremia. If the gauze is left in for several days, its removal is painful and may be followed by secondary hemorrhage, as occurred in one of the author's cases.

Personally, the author uses the following method for controlling bleeding after prostatectomy. The prostate is removed by the suprapubic method of Squier. With the finger in the rectum, the wound is elevated and then packed for a few minutes with dry gauze. The packing is removed and if any particular bleeding spot can be readily caught with forceps, this is done and the point ligated, but no time is wasted in making a search for bleeding points unless they are quite obvious. A large tube is placed in the bladder at the upper angle of the wound and fastened with a suture, and a very small

rubber catheter is passed through the urethra. The packing is removed and hot water is turned on through the catheter. The temperature at first is about 120° F. The large tube does not reach to the bottom of the wound. In this way a constant head of hot water is kept standing in the bladder. The bladder is sewed up while the solution is running, and care should be taken to remove all clots before the bladder is completely closed. If this is done and the solution is constantly running, the blood will be so diluted and carried off that it will not have time to clot. The interruption of the flow for even a few minutes for the first few hours after operation permits clotting and plugging of the tube. The tube is fastened securely in position by suturing it to the skin and is brought out from the upper angle of the bladder wound. A chromic or tanned catgut mattress stitch is put through the bladder around the tube and left long with the ends untied. Hot water, which may be semi-saturated with boric acid, should be kept constantly flowing through the catheter though plain hot water that has been boiled is all that is necessary. Overflow is prevented by having the large tube connected with an apparatus that consists of a small tin cylinder screwed on the top of a quart Mason preserve jar. There are two tubes in the top and one considerably larger about the middle of the side of the cylinder. This latter tube is slightly bent so as to form a syphon. The smaller tube in the top of the tin cylinder is connected with a faucet or with a jar containing water. The larger of the two tubes on top drains the bladder. The apparatus is screwed tightly to the jar which sits on a stool by the patient's bed at a lower level than the bed. It empties through the syphon into a slop jar or a large foot basin or tub. The flow of the water through the smaller tube on top fills the tin cylinder up

to the top level of the exit tube. This exit tube then overflows and, acting as a syphon, sucks up the water and diluted blood and urine from the bladder by creating negative pressure. The flow into the bladder should be small. Hot water is kept constantly in the bladder up to the level of the lower end of the large drainage tube. The suction may be made faster or slower according to the amount of water running into the apparatus from the smaller top tube. The advantages of this apparatus are that it keeps the patient dry, a head of hot water is constantly in the bladder, and the flow can be regulated at will.

Hemorrhage from the urethra, and particularly from the deep urethra, is sometimes severe. When the former practice of cutting deep strictures with a urethratome was in vogue, such hemorrhages were common. They may be controlled by the passage of a large sound or by a catheter over which a finger cot has been tied, the finger cot being inflated through the catheter when in place, as has been mentioned under the head of nasal bleeding. If these methods are not effective, an external urethrotomy should be done, a large tube introduced into the bladder and iodoform gauze packed around the tube. The bleeding may be controlled by catgut sutures if the bleeding points are accessible.

Hemorrhage from the uterus is due to the results of pregnancy or trauma, to a tumor, or to disease of the uterine tissues. When bleeding is from an incomplete abortion, the indication is to clean out the uterus, so permitting it to contract and close the vessels. If much blood has been lost and the patient is weak, the uterus sometimes does not contract and should be packed firmly with gauze, preferably with washed iodoform gauze. In hemorrhage from placenta previa, the usual obstetrical

rules are followed and an effort is made to bring down the presenting part of the child and plug the cervix. If the hemorrhage is severe, or if the life of the child is in danger, a rapid extraction should be made. Cæsarean section is advised for cases in which delivery by the natural route would prove difficult or tedious. Tears of the cervix sometimes cause severe bleeding which is controlled by sutures. Tanned catgut, silk, or silkworm gut may be used; plain catgut is absorbed very rapidly in this location. Sometimes secondary hemorrhage occurs after operations for tears of the cervix or for amputation of the cervix as late as the tenth day and even when the bleeding at the time of operation was insignificant. Such hemorrhages are difficult to explain, but are said by some to be due to a mild infection. They are more frequent after the use of plain or chromic catgut. If hot douches and packs do not readily control the secondary bleeding, the cervix is sutured with silkworm gut which can be removed after two or three weeks; it would be unwise to try catgut a second time. Bleeding from a benign tumor, such as a submucous fibroid, is often due to the fact that the tumor acts as a splint and prevents the uterus from contracting on the blood-vessels. If such a tumor is removed the hemorrhage stops. A submucous fibroid is often extruded through the cervix. Bleeding from cancer should, of course, be controlled by a radical hysterectomy if the disease admits of such an operation. If not, thorough curetting, followed by an application of the actual cautery, or the Percy cautery, will usually check the hemorrhage. There is a form of endometritis, accompanied by some change in the blood-vessels of the uterus, which is particularly liable to bleed.[4] While these

4 Cullen: Surgery, Gynecology & Obstetrics, October, 1913.

cases are often cured after one or two curettements, sometimes the bleeding recurs in a few months and demands hysterectomy. In one of the author's cases after thorough curetting on two previous occasions, the patient became exceedingly anemic from the bleeding, which again recurred, hemoglobin falling to twenty. After transfusion, hysterectomy was done and the patient made a prompt recovery. Radium, applied to the uterine cavity, is said to be very effective in controlling chronic bleeding from the uterus. The application of heat by water or steam has already been referred to.

After chronic uterine hemorrhage, not infrequently the patients become accommodated to a low hemoglobin, as has been pointed out by Byford, and the tissues by some form of compensation seem sufficiently nourished. However, in this condition the patient's resistance is low and she will easily succumb to a disease that she could normally resist.

Hemorrhage from the extremities where a tourniquet can be applied, may be dealt with on general principles. If a tourniquet is used, it should not be permitted to remain longer than an hour and a half, and it should be tight enough to constrict absolutely the arteries. It is applied preferably on the thigh or arm. No motion of the limb should be permitted when the tourniquet is on for fear of rupturing the muscle. An emergency tourniquet can be made either of elastic material, such as suspenders, or of a handkerchief or towel. This may be tied tightly and a long pencil or rod slipped underneath and twisted in such a way as to tighten the towel or handkerchief. Thus, any reasonable amount of pressure can be exerted. If the hemorrhage is not profuse, packing with gauze together with elevation of the limb and the

application of a bandage over the dressing is usually sufficient. According to recent views of military surgeons packing should not be used in the wound as it predisposes to infection, but a gauze dressing and a firm bandage should be applied. If profuse and arterial, the finger should be applied to the bleeding spot until the wound can be enlarged and the vessel secured.

CHAPTER IX.

PATHOLOGIC HEMORRHAGE.

Pathological hemorrhage is due to some change in the blood, or in the ultimate capillaries. There may be a slight trauma or the hemorrhage may occur without trauma as frequently happens in purpura. The diseases in which pathologic hemorrhage most frequently occurs are hemophilia, chronic jaundice, purpura, and melena neonatorum. Purpura is really a symptom rather than a disease and may occur with hemophilia. It implies subcutaneous and submucous hemorrhages. The cause of melena neonatorum is not definitely known, but it seems probable that it is not due to a disease of the blood-vessels themselves or to an infection, but is a congenital malformation of the blood, the exact nature of which is unknown. In all of these diseases it is likely that there is some defect in the formation of fibrin ferment. Adis concludes that hemophilia is due to an inherited defect in thrombogen (prothrombin) whereby it is less readily activated than normal thrombogen would be. Sahli thinks the lack of coagulability is due to a deficiency of thrombokinase and that this in turn comes from some defect both in the blood corpuscles and in the endothelial cells. It is well known that hemophilic blood coagulates promptly on the addition of fibrin ferment, so that some process involving the formation of fibrin ferment is defective. Normal thrombus formation has already been mentioned, and the thrombokinase, which is supposed to be universal in the body and which acts

upon thrombogen to form fibrin ferment in the presence of calcium salts, may be at fault in hemophilia.

Some observers have noticed that the clotting of blood from a hemophiliac is not materially altered if taken from an old wound, but when blood from a fresh wound is allowed to drop into a test tube, the corpuscles soon fall to the bottom and sometimes clotting does not occur for several hours. Hemophilia is a hereditary disease and usually occurs in males, though the tendency toward this disease may be transmitted by females. The ratio has been given variously as from four males to one female up to as high as thirteen males to one female. Osler mentions families that have been noted as hemophiliacs for a number of generations.

In the study of the blood of the hemophiliac, nothing definite has been found. It is supposed that the blood platelets are usually diminished in number. In two cases of hemophilia Cabot found white blood corpuscles and red corpuscles both considerably reduced. Wright has found a small number of white corpuscles with a deficiency in the percentage of polynuclears, while others have found a leukocytosis. The one constant feature seems to be a small number of the platelets.

In most instances, the bleeding of a hemophiliac comes from some slight injury. The majority of cases reported are from the nose, or from some part of the mouth. Hemorrhage also comes from the intestinal tract, urethra, stomach, or from any part of the body. The slightest trauma, such as pulling a tooth, a scratch from a cat, or even mosquito bites may cause a continuous and almost uncontrollable hemorrhage. Sometimes purple spots from subcutaneous hemorrhage appear beneath the skin or mucous membrane. Often the joints are painful and enlarged, the knee and elbow being fre-

quently affected. This is due to hemorrhage into the joint. Operations upon such joints are always exceedingly dangerous.

Treatment of hemophilia consists in the administration of certain drugs, in local compression, and in serum therapy. If the bleeding is from a small place sometimes the application of cold is useful. When it is necessary to extract a tooth in a person who is suspected of being a hemophiliac, it is well first to freeze the gums with ethyl-chloride. The local application of suprarenal extract has been advised and may be of some service. Unfortunately, while contracting the vessels greatly at the time of application, it causes a secondary paralysis as a result of this intense contraction, and may eventually make the hemorrhage worse. The internal administration of calcium in some form has been advised. It may be given per rectum as chloride of calcium, twenty grains three times a day, or by mouth or rectum as lactate of calcium in similar doses. The administration of a large dose of calcium or giving it too frequently, sometimes seems to have the opposite effect and will delay coagulation instead of increasing it. The local application of gauze soaked in a one or two percent solution of calcium chloride has been advised. The application of heat, particularly in the form of hot water, occasionally checks the bleeding.

Among the general measures of treatment of hemophilia, are regulation of the diet, proper personal hygiene, and fresh air. A nutritious diet including an abundance of milk is exceedingly important. Milk is supposed to have a double value on account of the calcium lactate it contains. The internal administration of thyroid extract, grains three, three or four times a day, has been followed by beneficial results. In one reported

case ovarian extract proved successful after other remedies had failed. Serum therapy should be used in addition to local treatment, if the hemorrhage is not soon controlled. This is really the most logical method of treatment, as it is generally agreed that the cause of the hemorrhage is some defect in the fibrin ferment. Foreign serums have been used. Of these the most valuable is the serum of the rabbit or the horse. From ten to twenty cubic centimeters may be injected into the veins or subcutaneously. Serum from a human being is best, though that from a horse or rabbit may be used with good effect. Sometimes the antitoxin of diphtheria will afford a satisfactory serum. The serum from cattle or dogs is peculiarly toxic to man and should not be employed under any condition. Any serum soon loses its power to cause coagulation and consequently should always be employed fresh.

The active principles of the serum obtained from horses seem to produce satisfactory results and to exert no deleterious effect. The dried serum from a horse which will keep indefinitely under proper conditions has been put upon the market under the trade-name of "Coagulose." It seems to have some advantages over the administration of the crude serum.

If hemorrhage has been going on for some time and the patient's hemoglobin is reduced to the neighborhood of twenty, transfusion of blood is indicated, not only because of the benefit of the serum therapy but because transfusion supplies red corpuscles. Many cases have been successfully treated by transfusion that did not respond to other treatment. Sometimes transfusion is not successful, but as it is used only after other remedies fail, even a small percentage of cures is gratifying.

The donor in transfusion for hemophilia should not

be a blood relative. It is likely that a blood relative, particularly if close, may have the same kind of defect in the formation of fibrin that the patient has. The following case, which is reported in detail, is interesting partly from this fact.

The patient, a man about forty-five years of age, was admitted to the University of Minnesota Hospital in the service of Dr. A. A. Law, and operated upon for appendicitis by Dr. Law's assistant on June 18, 1913. Two days later there was bleeding from the wound, bladder, and bowels. He was given forty cubic centimeters of normal serum in divided doses and also calcium lactate, but with no benefit. At the courteous invitation of Dr. Law the author transfused the patient on June 21. His condition at that time was very bad, pulse weak and running, hemoglobin twenty-eight, and he was still bleeding. The coagulation time of his blood was an hour and a half. The patient's son, a robust young man, was the donor. The patient seemed much benefited, though the coagulation time was not greatly decreased. The following day his hemoglobin was thirty-eight—an increase of more than one-third—and his coagulation time was seventy-five minutes, a decrease of fifteen minutes, and he was still bleeding. On June 23, two days after the transfusion, hemoglobin had dropped to twenty and the patient was practically in a dying condition. His blood did not coagulate in an hour and a half and he continued to bleed. Dr. Law did a transfusion with the patient's wife as donor. He used a cannula and there was a strong flow of blood for fourteen minutes. The patient was greatly improved, the coagulation time coming down to four and a half minutes after the transfusion, as against more than an hour and a half before, and the hemoglobin increasing to thirty-eight. The im-

provement continued and on July 26, hemoglobin was fifty-six and coagulation time seven and a half minutes. He then developed some bowel disturbance and, on August 1, there was bleeding from the gums and coagulation time was one hour. Thirty cubic centimeters of whole blood were injected subcutaneously and the bleeding stopped. On August 5, the pulse became bad, there were sighing respiration, extreme pallor, and tarry stools. Dr. Law did another transfusion, but the patient died within three minutes after the blood was turned on. He was really dying when the transfusion was begun. Autopsy showed nothing of significance except pulmonary edema and a number of small hemorrhages in the mucous membrane of the ileum. The most interesting feature of this case is the marked difference in the effect of the blood from the patient's son and from his wife. The former probably had the same defect in his blood as the patient, but to a limited extent. Though hemoglobin was increased more than a third by the transfusion, the coagulation time was only slightly decreased and the bleeding was not stopped. However, with the alien blood of his wife the coagulation time was brought down from more than an hour and a half to four and a half minutes and the bleeding was checked at once. The course of this case suggests strongly a deficiency in fibrin ferment, possibly in the thrombokinase element; and as long as the supply of this from an alien blood lasted, the patient did well. His own tissues were apparently unable to furnish it.

Purpura, like jaundice, is usually a symptom, though Henoch's purpura may be classified as a disease in itself. This latter disease is seen in children and is accompanied by intestinal disturbances, such as pain, diarrhea and vomiting, and often by splenomegalia. Pur-

pura is associated with various infections such as septicemia, pyemia, measles, scarlet fever; or occurs after some toxic or drug poison, as belladonna, snake venom, ergot; or after toxins of metabolic disturbances, as Bright's disease, scurvy; or after nervous affections, such as locomotor ataxia or transverse myelitis; or it may occur from some derangement in the intestinal tract. The immediate treatment of purpura if hemorrhage is a marked feature, is practically the same as that of bleeding from hemophilia. The cause, however, should be removed whenever possible, and treatment must be directed along this line. Aromatic sulphuric acid and turpentine have been recommended for purpura, apparently on general principles.

Melena neonatorum is probably merely another form of purpura. Serum treatment should always be tried and if the hemorrhage is severe and not controlled by the injection of fresh serum, transfusion of blood should be done. In a young baby it is necessary to use the saphenous vein or the femoral for transfusion.

Hemorrhage during chronic jaundice is always a serious complication and at least one-half of these cases end fatally. Treatment is the same as that of hemophilia. If operation is necessary, the patient should be given calcium chloride or lactate, as recommended in the treatment of hemophilia; also thyroid extract for two or three days before operation seems beneficial. Care should be taken to separate as few adhesions as possible. A hypodermic injection of camphorated oil, five to ten minutes two or three times a day, acts as a stimulant and seems to have a beneficial effect upon these patients.

CHAPTER X.

THROMBOSIS AND EMBOLISM.

Thrombosis.

The manner of formation of a thrombus has been described in Chapter V. Thrombosis is particularly liable to occur in veins, which is largely due to the sluggish circulation that permits comparatively prolonged contact of blood cells with an injured area of endothelium. In a rapid current, as the arterial blood, the cells are in contact for such a short time that there is not the same opportunity for damage to them. The composition of venous blood may also favor thrombosis in the veins.

Venous thrombosis is most commonly met with as phlebitis in the saphenous or femoral vein of the leg, usually of the left leg. The lesion in the endothelium of the vein may be from trauma or from chemical or bacterial injury. The most common cause of phlebitis is infection. The infection may be mild but the toxin elaborated by the germs increases the coagulability of the blood by the destruction of blood cells which release more of the elements of coagulation. The vascular endothelium may be injured by the contact of the toxins. In the slow flow of a venous stream a toxin which is mildly irritant but which comes in prolonged contact with the intima often produces a slight change in the vascular endothelium that is a starting point for a thrombus. After the thrombus has begun it extends by additions to the clot from the blood current until the whole vein may be involved.

The cause of the frequent involvement of the left saphenous vein as compared with the right is probably due to the slightly longer course of the left vein before it reaches the vena cava. The pressure of the sigmoid flexure may have something to do with it. Some cases of phlebitis are difficult to explain. A certain percentage of abdominal operations is followed by phlebitis of the leg, even after the wounds have healed by first intention. It may be possible that the metabolic products incident to the healing of the wound cause an injury to the intima of the vein similar to that produced by infection. Osler and others report cases of thrombosis of the inferior vena cava, evidenced by the symptoms and by the superficial collateral circulation. The sinuses of the dura are also the seat of thrombosis. The lateral sinus is particularly liable to be involved and this is a serious condition. Septic clots often break up and by distribution over the body cause pyemia or septicemia.

Thrombosis of an artery is not common. An embolus usually derives its origin either from a thrombus that has formed in one of the branches of the pulmonary veins or from vegetations from the valves of the heart.

A thrombus is always primarily due to some injury of the intima of the blood-vessels; consequently, the thrombus is secondary. This doctrine was held by John Hunter. Virchow, however, claimed that the thrombus was usually primary and the lesion in the vessel wall was secondary. This teaching has been practically abandoned. Adami [1] states that a thrombus is always associated with local disturbance of the vascular wall and it is doubtful whether a thrombus ever originated as a process of free clotting of the circulating blood. While the direct cause is some injury to the endothelium of the intima, the con-

[1] Principles of Pathology, Vol. II, page 59.

dition of the blood both as to composition and as to the rate of flow, constitutes a very strong predisposing cause. Changes in the blood-vessel that cause the formation of a clot are induced by direct trauma or by disease of the blood-vessel itself, as in arteriosclerosis or atheroma. These changes may also be secondary to some irritating substance in the blood, derived from deranged metabolic processes from the ingestion of irritating substances, or caused by a toxic bacterial product. Whether a slight injury of the vascular wall is always followed by clotting and the exact extent of the thrombus when formed depends upon the condition of the blood itself. Thrombosis frequently occurs after the acute infectious diseases, such as typhoid, measles, scarlet fever, smallpox, and after pyogenic infection. It may occur during gonorrhea, syphilis, gout and various forms of anemia, especially that following hemorrhage. Most of these conditions probably act primarily by injuring the intima and secondarily by causing the essential elements of clot formation to be abundantly present in the blood. It is well known that most of the constituents of a thrombus, particularly fibrinogen, are largely derived from the disintegration of the blood cells. The presence of toxic material in the blood has a destructive effect upon these cells, so a slight lesion of the intima which, under ordinary conditions, might not cause thrombosis, will produce extensive clotting when the blood contains a large amount of fibrinogen and thrombogen.

The changes in the blood itself may, however, be of such a nature as to retard clotting. The absence of the proper amount of calcium salts together with the somewhat obscure influence of such diseases as malaria, yellow fever, scurvy, jaundice, hemophilia, pernicious anemia, leukemia and alcoholism decreases the coagula-

bility of the blood. An excessive amount of oxygen, the restriction of food, ingestion of large quantities of water, smoking of tobacco, are said to delay clotting. The injection of certain chemicals, particularly the extract from the head of a leech, called "hirudin," retards clotting. The coagulability of the blood is also delayed by certain snake venoms and after poisoning by chloroform or prussic acid. Clotting is accelerated and may possibly be produced within the blood-vessels by the injection of defibrinated blood or an emulsion of leucocytes, also by the injection of ether, gallic acid, or the bile salts. Extensive burns and severe frost bites promote thrombosis, particularly in the capillaries. The use of thyroid extract, and of gelatin, and the administration of milk and lime salts, together with the injection of a serum or "coagulos" in order to increase clotting have been referred to under the head of pathologic hemorrhage.

Blood platelets have an important rôle in thrombosis, and in the conditions in which thrombosis is most likely to occur these platelets are abundant. Their exact action is a matter of doubt. They are supposed by some to result from the destruction of the blood cells, whereas others claim they are the direct product of the large cells of the bone marrow.

The rate of flow of the blood has a marked influence upon thrombosis. When the blood cells are carried rapidly past a lesion on the intima, there is not enough time for the cells to be sufficiently injured in order to disintegrate and throw out the essentials of a clot. On the other hand, if the current is slow and the cells are in contact with the lesion for some time, they may disintegrate and the elements of clot formation are rapidly produced. For this reason anything that tends to retard the current of blood is a predisposing cause of thrombosis. Nat-

urally, under these conditions the veins are the most frequent site of thrombus formation. Occasionally, eddies or whirls in the blood current favor the formation of clots. This may be due to the fact that the same blood cells, instead of passing by the lesion of the intima and returning later after completing the circulation, are carried quickly back to it by the little eddies or whirls.

A thrombus is usually classified as a hyaline thrombus, a white thrombus, or a red thrombus. These are subdivided by various authors. The white thrombus, particularly as found in aneurisms, is probably a late stage of the red thrombus, the coloring matter derived from the red blood cells having been gradually absorbed. However, under certain conditions the white thrombus is deposited primarily. The common form of thrombus is the red thrombus. The hyaline thrombus is interesting but rare. It seems to be formed largely, if not entirely, from the blood platelets or from the shadow corpuscles of the red cells. They are largely found after some infectious disease or toxic material that causes hemolysis of the red blood cells. The white thrombus that occurs in the chambers of the heart or in the large vessels, is composed mainly of white corpuscles intermingled with a fibrinous layer. Under low power of the microscope, sections from a hyaline thrombus appear homogeneous, but under high power they are seen to be packed closely with blood platelets among which are a few white blood cells. This appearance may be varied in different portions. Purely fibrinous thrombi are sometimes seen in pulmonary vessels after pneumonia.

At the beginning of its formation, a thrombus is what is termed parietal or mural and does not occlude the whole vessel. As it enlarges, the vessel is completely filled. Thrombi sometimes occur on the valves of the

heart or the valves of a vein. The term secondary thrombus is applied to that formed around an embolus. Sometimes a thrombus is found loose in the heart, resulting from the detachment of a thrombus that forms in the chambers of the heart. This is called a "ball thrombus." As a rule, however, thrombi are always adherent to the interior of the vessel in which they originate and advance both peripherally and centrally, but extend most rapidly in the direction of the blood current.

A thrombus which at first is soft, later contracts and becomes more compact. The leucocytes undergo fatty degeneration and the red cells disintegrate. The fibrin becomes coarser and so-called organization will later occur, by which the leucocytes from the small vasa vasorum invade and remove the clot. The intima of the vessel is covered with granulations that replace the clot which is in time converted into a string of cicatricial tissue. When the whole vessel is occluded it generally becomes merely a fibrinous cord. Sometimes if all of the thrombus is not removed, spaces will be left which communicate with the blood current, the thrombus may present a small lumen and the blood current is partially restored. The changes in a thrombus depend to a large extent upon the condition of the patient. Usually, it is well advanced in a week. Sometimes a thrombus is calcified, and remains as a small round or oblong hard body called "a phlebolith" that may either be firmly imbedded in the walls of a vein which has been obliterated by the thrombus, or merely loosely adherent and capable of some motion. These are found very frequently in the venous plexuses about the broad ligament in women and about the prostate in men.

The change a thrombus undergoes depends to some extent upon its position and size. A small thrombus that

does not entirely occlude the vessels may be completely absorbed either by the leucocytes with a solution of the fibrin, or if larger the thrombus may break down into a thick, opaque fluid that is sterile, but resembles pus in appearance. It contains globules of fat, together with debris and some red corpuscles, and is the result partly of the work of the leucocytes and partly of the digestion of some ferment.

The so-called organization of a thrombus is a misnomer, for the thrombus is absorbed and is replaced entirely by connective tissue. Granulations spring up from the surrounding endothelial cells. The leucocytes invade the clot and carry it away and the granulations form connective tissue. This may convert the vessel into a fibrous cord, or may result merely in the formation of bands or in permanent contraction of the vessel at the site of the thrombus.

Canalization of the thrombus is an interesting but not a very common termination. In this condition the center of the thrombus is pierced by a small blood-vessel. According to Adami, the most probable explanation is that the capillaries which penetrate the thrombus to carry leucocytes communicate with each other and eventually communicate with each end of the thrombus, thereby establishing a channel which may dilate and form a larger vessel. As has already been mentioned, calcification of the thrombus may occur. An aseptic thrombus does not break up as readily as one that is septic. A septic thrombus often goes to pieces, and so spreads septic material in the circulation, causing pyemia; or it may be surrounded by a further thrombus not septic which encapsulates the septic material and so localizes it.

The cause of a thrombus has been discussed in a gen-

eral way, but occasionally thrombi are found that are difficult to explain. The thrombo-phlebitis of the left leg following operations has been referred to as an example of this. Occasionally, after an operation, especially after an abdominal operation, thrombosis of the left femoral or saphenous vein occurs. This is often found after slight suppuration or particularly after a septic course, but not infrequently thrombosis occurs when there is evidence of a clean wound and perfect healing. Clark has written extensively on this subject and thinks thrombosis is due to the retractors which traumatize the abdominal wall and cause thrombosis of the superficial or deep epigastric veins, and that this thrombus extends to and involves the iliac and femoral veins. He explains left-sided thrombosis after an operation on the right side of the abdomen by the free communication between the veins of the two sides. The left side is the one most frequently involved. The reasons usually given are that the course of this vein including the iliac trunk is slightly longer than that on the right side, it is compressed by the arteries in the pelvis under which it passes, and often it is also further compressed by an overloaded sigmoid. The symptoms appear about the second or third week. The left leg is affected twice as frequently as the right, and sometimes both legs are involved. The disease rarely begins earlier than eight days, nor does it appear later than thirty. The second week after operation is the most favorable time for the development of thrombosis. Pain in the calf of the leg and tenderness over the course of the saphenous vein which begin the second week of convalescence from an abdominal operation are always suggestive of phlebitis and if there is a rise of temperature accompanied by some swelling, the diagnosis can readily be made.

The treatment of this condition is not very satisfactory. Conservative treatment consists of rest in bed, elevation of the leg, enclosing it in cotton, which is lightly bandaged, and the application of opium and lead water or belladonna ointment. These remedies usually give relief in the course of time, though swelling will be present, particularly after walking, for weeks or months.

In septic thrombosis in the leg or arm, the treatment should be directed largely toward the source of infection. If the infection is in the leg and the patient runs a high temperature with pyemic symptoms, the vein should be excised or ligated, or amputation should be performed if the symptoms are severe. In amputation of the leg in which there is sepsis and thrombosis of the veins, great care should be taken in the operation. Rough handling, the application of an Esmarch, or even a tourniquet, may loosen the clots and force into the circulation a fatal dose of sepsis. Amputation in such instances should be done by the dissection method without a tourniquet, cutting the flaps carefully and controlling small bleeding points by forceps and accurately dissecting out the large vessels, tying or clamping them before division. The limb should not be moved until it is completely severed from the body. In this way but little damage is done to the tissues, the traumatizing effect of the tourniquet is dispensed with, and the possibility of the tourniquet forcing septic thrombi further along in the veins is obviated.

In thrombosis of the lateral sinus and the internal jugular vein, which most frequently occurs as a result of sepsis following mastoid or middle ear suppurative disease, the vein should be promptly ligated or excised. Manipulation must be as gentle as possible, first exposing the vein near the root of the neck and ligating it be-

fore any clot is dislodged. In one case of thrombosis of the internal jugular from a mastoid suppuration, the author excised the jugular; in another instance when sepsis came from the lower jaw, the jugular was carefully dissected free and the branches which emptied into it were ligated. Both patients were very septic with rapid and feeble pulse. Both recovered after a stormy convalescence.

Embolism.

Embolism literally means blockage of an artery or vein by some substance that did not originate in the region at which the blockage occurs. The substance is the embolus. The most frequent source of an embolus is a thrombus, particularly a septic thrombus which easily breaks up and gives rise to showers of small clots that form emboli. This is the generally accepted description of pyemia. Emboli more commonly come from a thrombus, but may be from fat, air, pieces of foreign body, portions of a tumor, or parasites. The formation of an aneurism in the mesenteric artery of a horse from the *strongylus armatus* is a well known example of an embolus from a parasite. Pieces of tumor or calcareous matter or, occasionally, in leukemia, large masses of leucocytes may form emboli. Cases have been recorded in which a bullet entering the heart or large blood-vessels has acted as an embolus and has been carried by the blood stream until arrested by the narrowing caliber of the artery.

Naturally, emboli occur more frequently in arteries than in veins, though venous emboli are by no means uncommon. The portal vein is particularly liable to emboli because it acts somewhat as an artery by receiving blood and eventually emptying it into smaller channels.

Venous emboli in the general circulation occur in two ways, by retrograde movement in which the current of blood is temporarily reversed, and by the persistence of the foramen ovale through which a thrombus may be forced back into a vein.

Cardiac emboli are very rare, because even a large thrombus from a vein is usually carried through the heart and arrested in the pulmonary arteries. Sometimes, however, the heart may be completely blocked, which, of course, results in sudden death. Emboli are more likely to lodge in the arteries of the lower extremities because of the fact that their large vessels are more directly in the axis of the main arterial current. It is probable that many emboli carried into the legs do not give serious symptoms, and as an embolus in the cerebral or in the mesenteric arteries is usually a very grave or a fatal condition, the incidence of emboli in these latter situations has appeared abnormally great. The pulmonary artery is frequently the site of emboli from a detached thrombus that goes from the systemic veins into the right side of the heart.

Welch, whose classical article on thrombosis and embolism in Albutt's "System of Medicine" is the basis of most writings on this subject, believes that embolism is most frequently detected in the renal, splenic, cerebral, iliac, and other arteries of the lower extremity, axillary arteries of the upper extremity, ceoliac axis, the central artery of the retina, the superior mesenteric, the inferior mesenteric, the abdominal aorta, and the cardiac coronary arteries. This, he says, is the relative order of frequency so far as symptoms appear, though more than likely the actual occurrence of embolism is in a different ratio as has already been explained, because of the fact that in many of the arteries first mentioned the slightest embolus will

give symptoms, whereas an embolus may occur in arteries of the lower extremities with but few if any symptoms. A "paradoxical" or "crossed" embolus results from a thrombus that originated in the venous side and is found plugging one of the systemic arteries. This, of course, can only take place by the passage of the embolus through the patent foramen ovale. The persistence of a patent foramen ovale is by no means uncommon and it is said that in one out of three hearts some such communication exists, though it is usually small and valve-like. In some cases, however, it is large and direct.

The capillaries of the lungs are quite large and easily distended. It is possible for articles of considerable size, even tissue cells, to pass through the capillaries of the lungs without being arrested. Adami mentions an experiment in which scraped material from the liver of a rabbit was injected into the systemic vein of another rabbit. After a few minutes the second rabbit was killed and small masses of liver cells were found in the arterioles of the kidney. Examination of the heart showed the foramen ovale was closed.

Capillary emboli occur from small masses that are numerous and yet are not large enough to arrest the circulation in a large artery. It has been noticed that the pigment remains of the malarial parasite may be arrested in the fine capillaries of the brain and kidney, resulting in functional disturbance of these organs. Bacteria and cells from malignant tumors often form emboli in the capillaries.

The presence of air as emboli is more or less dangerous, depending upon the vein into which the air was taken, and the suddenness of the intake as well as the amount of air aspirated. Such an accident was not uncommon in preanesthetic days, when the patient

would often hold his breath from the pain and suddenly take a deep inspiration. The hissing, sucking sound of the air entering is very noticeable. The slow entrance of air into a vein at some distance from the heart can usually be taken care of without any untoward event. Nitrogen and oxygen are normally carried in solution in the blood stream, either in combination with the cells or in the plasma of the blood, and a small amount of air introduced slowly is readily dissolved. The amount of air that can be given in an ordinary hypodermic syringe, if injected slowly into a distal vein, would in all probability occasion but little if any disturbance. However, air injected suddenly into the veins of the neck near the heart produces serious symptoms at once. Formerly many deaths from supposed air embolism were probably cases in which gas formed after death, such as occurs from the bacillus aërogenes capsulatus, but even including such instances death from air embolus has undoubtedly been more frequent in preanesthetic days than now. Air when taken in and warmed by the temperature of the blood expands and forms a much larger volume than it would naturally have in the normal temperature of the room.

Though air embolism is not common, such accidents occasionally occur now. Within the last ten years the author has had two cases, one of them terminating fatally. In this case the author operated upon the neck for a large recurrent carcinoma, which had infiltrated and blocked the internal jugular vein. Contraction of the cancer had distorted the anatomy and pulled the internal jugular considerably out of its normal position. As the head of the patient was slightly elevated and the vein blocked it was constantly collapsed and resembled a band of fascia. In an effort to dissect the

common carotid, this vein was cut, as it seemed merely a band of connective tissue. It was picked up and was seen to have a shining internal surface. Air rushed in immediately and the vein was then clamped. It was recognized at once that a mistake had been made, though no blood at any time escaped through the vein. The patient's head was lowered and he seemed to improve for a short while. He was given intravenous salt solution with adrenalin and his pulse was better for about five minutes. Then his head was raised and his pulse became weaker. He died in about fifteen minutes from the time the vein was cut.

In the second case, during a dissection of tubercular sinuses and tissue over the sternum where there were several superficial veins, one of them was cut and immediately the hissing sound of air entering the vein was heard. The vein was at once compressed with the finger and then a wet compress was placed upon it and the tissue sutured. The patient's pulse became rapid and rather weak, though after a few minutes it improved and he made a satisfactory recovery.

The mode of death after air embolism has been a subject of considerable controversy. The two main theories are, first, that it is a cardiac death. The air is warmed and expands rapidly. It accumulates behind the tricuspid valves and renders them inefficient. The pressor terminals in the heart are unaccustomed to air instead of fluid blood and are also deranged. The second theory is that death is caused by multiple air emboli in the pulmonary capillaries of the lungs. These small bubbles of air cannot pass through the capillaries of the lung but block them; thus death occurs in the same manner as when the pulmonary arteries themselves are occluded. It is thought by some that gas may eventually

make its way to the left side of the heart and that the emboli in the brain may be the cause of death. This is not as probable as the other two theories and according to the experiments of Wolff the theory of death from air emboli in the pulmonary capillaries is more reasonable.

A form of embolism from air or from gas that is frequently fatal occurs in those who work in compressed air and is supposed by many to be the cause of the so-called "caisson disease." After working in compressed air for some time if the individual emerges suddenly he often becomes a victim of nervous disturbances that may quickly prove fatal. There are various paralyses and other symptoms showing lesions of the spinal cord. These are probably due to the fact that the tissues take up under increased pressure much more gas than under ordinary atmospheric pressure, and when the pressure is suddenly removed the gas is released. If the pressure is quickly reduced, the blood and tissues can no longer hold the excess of free nitrogen in solution, though the oxygen may be taken care of. The nitrogen separates in the form of bubbles that grow in size as the pressure is diminished and are carried by the blood stream, forming gas emboli. This is most serious when the brain and spinal cord are affected.

The results of emboli depend upon their location and are the same as after occlusion of an artery. If derived from a thrombus, the changes and termination following the localization of the emboli depend partly upon whether there is infection and whether the infection is localized by a sterile layer of thrombus around the infected material.

The treatment of embolism depends upon its form and location. In air embolism various suggestions have been

made. One is that a rubber tube or catheter be inserted in the right internal jugular vein and pushed into the heart, the air being drawn off by this means. It is rather impracticable, for it is likely that more air will be introduced by this method, particularly as the tube will probably not fit the vein accurately. The main treatment should be directed toward general stimulation of the heart, together with lowering the head, and the administration of oxygen. The heart is stimulated in order to prevent collapse and at the same time to force the air through the capillaries of the lungs and to hasten its solution in the blood stream. Of course, the immediate treatment at the wound consists in pressure on the injured vein. This should be done with the finger at first and later with a moist compress which is fastened securely in position for several days. Usually the trunk of the vein can be compressed toward the heart and the vein clamped and tied; though the application of a moist compress or the finger should be maintained until the patient has somewhat reacted or until it is entirely certain that ligation or clamping can be done without the possibility of more air entering.

The preventive treatment of air embolism should be borne in mind when operating on the neck and in the axilla, as only the regions that are nearest the heart and consequently subject to the so-called venous pulse are in danger of admitting air. The deep jugular vein is fixed rather firmly to the fascial planes of the neck, which to some extent prevents it from collapsing readily. When such a vein is inflamed and the walls made stiff, the danger is still greater. In injuries to the femoral or saphenous veins or even to the veins in the pelvis there is but a slight chance of air embolism, though such cases have been reported. Usually here the pressure is positive

and the distance is too great from the heart for the venous pulse. In operations upon the neck or axilla the incision should be sufficiently long to enable the operator to identify the structures. It is best to make the incision low in the neck first and if the internal jugular is not distended, a sponge or a wad of gauze shoved in behind the clavicle, as suggested by Mayo, will produce enough pressure upon the vein to keep it distended. With ordinary skill there should be no danger in dissecting a distended jugular vein. It is when it becomes collapsed that there is great risk of injury.

Fat embolism occurs from the rupture of fat cells and the discharge of their contents into the blood stream. It comes on particularly after injuries to long bones in which the fat marrow is involved, for the veins in the haversian canals cannot readily collapse as they are fixed to the bony wall. It may result from injuries to the mesentery or to the fat beneath the skin.

Fat embolism appears later than shock or air embolism and except in the region drained by the portal vein it is always found first in the lungs. About sixty per-cent of all cases are caused by fractures and about seventy-five percent are caused either by fractures or by some inflammatory disease of the bone. Other cases are due to injuries or suppuration of the soft parts. The fat from fracture of a bone enters the veins about the third day after the injury because the veins in the haversian canals are held open by the bone and so are prevented from collapsing and their thrombi may loosen at this time. Fat embolism occurs as a rule from thirty-six to seventy-two hours after injury, though occasionally it may be much later. There may be death from the sudden blocking of the pulmonary vessels. The

symptoms are usually pulmonary at first, severe pain in the chest, difficult breathing, cyanosis, and sometimes expectoration of blood. Temperature at first is subnormal but soon rises. The physical signs are rather indefinite, though there are many coarse rales and later consolidation occurs. If the patient does not die soon some of the fat is forced through into the systemic circulation and symptoms of embolism of the brain, such as convulsions, paralyses, or coma, may occur. The kidneys are also affected and often fat may be demonstrated in the urine. Fat, however, is frequently found in the urine in small amounts after fractures when there are no symptoms of embolism. It is probable a great many cases of fat embolism occur that produce such slight symptoms they are not recognized. Only the severe cases are reported.

The treatment of fat embolism consists partly of preventive measures, such as avoiding unnecessary injury to fat during operations, particularly to the fat marrow of bone. Large quantities of fat when injured should be drained. It is well not to sew fat but if sutured the tension on the stitches should be very slight. Several cases of fat embolism have been reported after so-called bloodless operations for congenital dislocation of the hip, and it is one of the dangers of this procedure. Riener advises placing a constricting band to render the limb bloodless and after the operation, before the band is removed, he inserts a cannula into the upper end of the saphenous vein pushing it on to the femoral and so draws off the first flow of blood, which is supposed to contain fat. This, however, is very radical. Treatment on general principles is about all that can be done. Cardiac stimulation, artificial respiration if necessary, and the administration

of oxygen are indicated. Oxygen not only makes the most of the impaired lung that is left, but tends to favor the elimination of fat by oxidation.

Pulmonary Embolism.

Pulmonary embolism occupies a unique position because embolism here occurs in an artery, usually from a thrombus formed in some of the systemic veins. It is a condition that often comes without warning in a patient who is apparently convalescing satisfactorily. For this reason it is peculiarly distressing and tragic. The embolus originates from a systemic vein or from the heart and while it may be composed of various substances it is usually from the loosened clot of a thrombus. Whatever predisposes to the formation of a thrombus, necessarily tends towards causing pulmonary embolism. Phlebitis, whether traumatic or septic, and operations involving a venous plexus are marked predisposing causes. More than one-half of all cases of pulmonary embolism are from operations upon the uterus or its annexa. The appendix is drained by the portal circulation, but thrombosis of the systemic veins may occur after operations on the appendix, as explained under "thrombosis" (page 183). Hysterectomy is responsible for about one-third of the cases, and appendicitis for about one-tenth. Two fatal cases of the author's followed suprapubic cystotomies. When operation is followed by the necessity of remaining in bed for a long time with slow blood current in the veins, the possibility of a loosened thrombus is much greater.

The symptoms of pulmonary embolism depend, of course, upon the effect on the lung and this in turn upon the size of the embolus and the location of the obstruction. Undoubtedly many minute emboli occur without

any obvious symptoms. Very probably the pain in the side of the chest that patients often complain of after operation is due to a slight embolus near the pleura, though if small the physical signs may not be noted. Larger emboli give more symptoms with an area of consolidation. If there is sepsis the symptoms and signs of septic pneumonia are present, but if the emboli do not contain septic germs, the symptoms will be dependent upon the size of the embolus and the amount of lung tissue that is put out of commission. Sometimes bloody expectoration occurs.

The larger emboli either cause instant death or death within a few minutes. This occurs most frequently from the second to the fourth week after operation. The patient may be feeling perfectly well, but following some operation upon the pelvic organs, he sits up, the thrombus is loosened and lodges in the pulmonary arteries. The patient complains of pain about the heart and becomes purple, the pulse ceases and if the embolus is large death occurs in a few minutes. If the pulmonary artery is not entirely plugged he may live for hours or sometimes even for days. Occasionally, recovery after the most alarming symptoms has been noted. The patient is cyanotic, respirations are rapid, and the eyes protrude. The pulse is very weak, quick and irregular. The pupils dilate and the veins in the neck are swollen. The patient is covered with a cold sweat. Occasionally there is delirium, coma, or convulsions if death is not immediate. These symptoms occurring suddenly and after rather quick movement of the body or legs, such as the first effort to rise in bed, make the diagnosis almost certain.

The treatment depends upon the type of case. If the embolus is small and symptoms slight, treatment on general principles is all that can be done. Cardiac stim-

ulants together with the proper nourishment to carry the patient over the critical stage and prevent infection are indicated. Possibly the administration of large doses of urotropin, fifteen or twenty grains four times a day for two days, which is partly eliminated from the mucous membrane of the bronchi is also advisable. The preventive treatment has already been mentioned under "thrombosis." It has been advised to give citric acid several times a day in such diseases as typhoid where there seems to be an increased tendency to clotting. Decalcifying milk by adding citrate of soda has also been suggested as the lactate of calcium increases clotting and the citrate of soda is supposed to neutralize the effect of the lactate of calcium. If sepsis occurs the ordinary treatment for pneumonia is carried out. In large emboli oxygen and cardiac stimulants should be given.

Direct treatment has been advocated by Trendelenburg. He has elaborated an operation based on experimental work. He introduced into the internal jugular vein of a calf a piece of lung tissue aseptically removed from another animal. As soon as the symptoms of pulmonary embolism appeared, operation was done and the embolus removed. The calf, which was eight weeks old, recovered from the operation and three months later was killed and the specimen consisting of the heart and large blood-vessels adjoining was exhibited before the German Surgical Congress at Berlin in April, 1908. The technique of this operation which is from the description by Willy Myer [2] is as follows:

A horizontal incision about four inches long is made upon the second rib on the left side, beginning at the left border of the sternum and dividing the skin, fascia, and

2 Annals of Surgery, August, 1913.

pectoralis major muscle. This incision is crossed by a perpendicular cut which begins below the sternoclavicular articulation and passes the cartilage of the third rib about one inch outside of the border of the sternum. It so avoids the internal mammary artery (Fig. 62). The two triangular flaps formed by this T-shaped in-

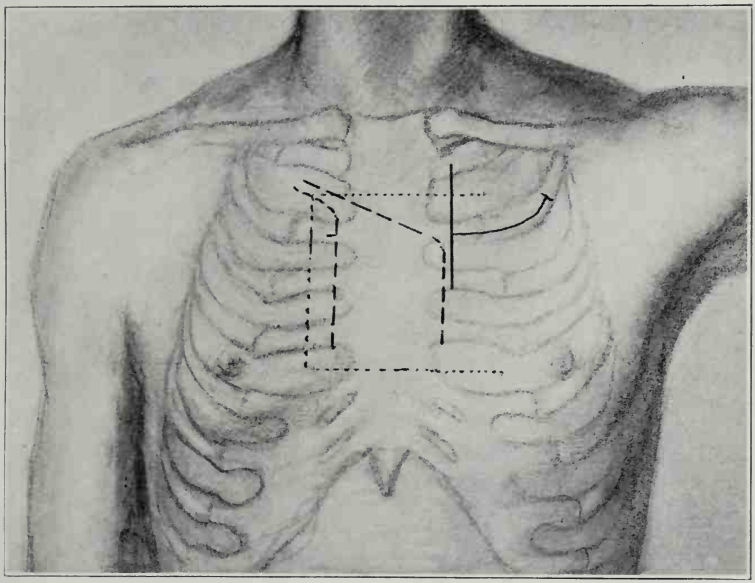

Fig. 62.—Various incisions for approaching the heart and pulmonary artery. That marked in a heavy line on patient's left is the incision of Trendelenburg for extracting a pulmonary embolus.

cision are then turned back. The second rib is isolated and divided at the external end of the incision. The rib is raised, twisted loose from its cartilage, and removed. The cartilage is then removed. The third cartilage is divided in a perpendicular line to give more space. If the pleura has not been opened by this time a T-shaped incision should be made through it corresponding to the original incision. The lung is allowed to collapse, which exposes the pericardium. The phrenic nerve and pul-

monary vessels are easily seen. The pericardium is divided just internal to the phrenic nerve. The wound is lengthened in an upward and backward direction until the entire upper half of the pericardium is incised. The lower portion is not cut and the heart is left in its normal position. All this is supposed to be done in five minutes. If possible either intratrachial anesthesia or differential

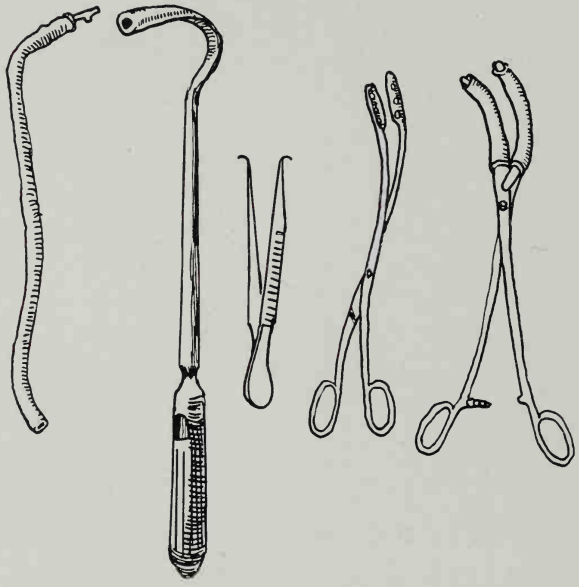

Fig. 63.—Special instruments of Trendelenburg for operation on pulmonary embolus. On the left is the elastic cord, and next to it the sound by which the cord is passed around the aorta and pulmonary artery. Next is the instrument for opening and elevating the incision. On its right is the forceps for extracting the embolism. The clamp for temporarily closing the incision is on the extreme right. (After Willy Myer.)

pressure should be used, but it is not necessary. With the help of an instrument devised by Trendelenburg and called a sound, a rubber tube is quickly drawn through the transverse sinus of the pericardium surrounding the ascending aorta and the pulmonary artery and is pulled up for compression immediately before the surgeon incises the pulmonary artery. A thin layer of fat with the

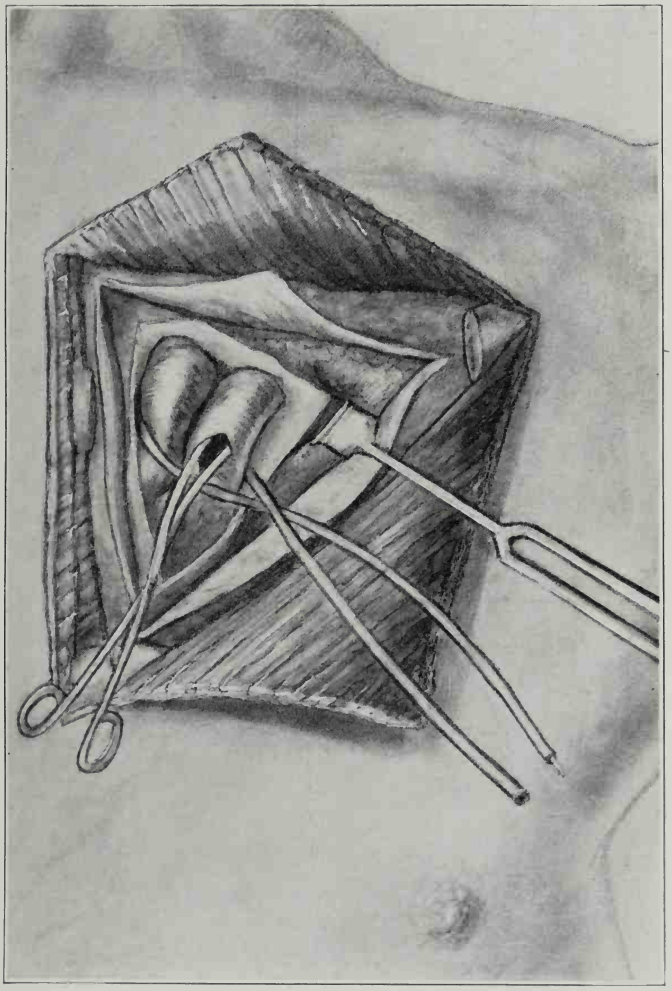

Fig. 64.—Pulmonary artery has been incised and forceps inserted to remove the embolus. (Willy Myer.)

viscera layer of pericardium is torn through and an incision of about one-half inch is made in the pulmonary artery. A special curved blunt forceps (Fig. 63) is introduced first into the main trunk of the pulmonary artery and then into the branches and any embolus or thrombus is grasped and extracted (Fig. 64). This must be done in forty-five seconds because interruption of the general circulation is not tolerated longer. The margins of the wound in the vessel are then lifted by special forceps (Fig. 63), and closed by a clamp, after which the assistant relaxes the elastic compression (Fig. 65). The circulation is thus reëstablished and the heart begins to beat very violently if it has not altogether ceased. If necessary, the constriction can again be tightened and another search made for the embolus, though the circulation must never be cut off for more than forty-five seconds at any one time. Closure of the wound in the pulmonary artery is done by interrupted stitches, while the clamp partly but not completely constricts the pulmonary artery. The wound in the artery should be quickly sutured, using fine silk. The pericardium and chest wounds are closed in the usual way.

According to Trendelenburg, in fifty percent of pulmonary embolisms only one branch of the pulmonary artery is first obstructed and here death does not occur until ten to sixty minutes after the first onset of symptoms. Fifteen minutes is supposed to be at the disposal of the surgeon in most of these cases and, with prompt operation, Trendelenburg claims some patients can be saved. The results of the operation show that no patient so far has survived, though one lived for four days and another died from pneumonia five days after operation. Twelve cases in all have been operated upon at Trendelenburg's clinic without a permanent recovery.

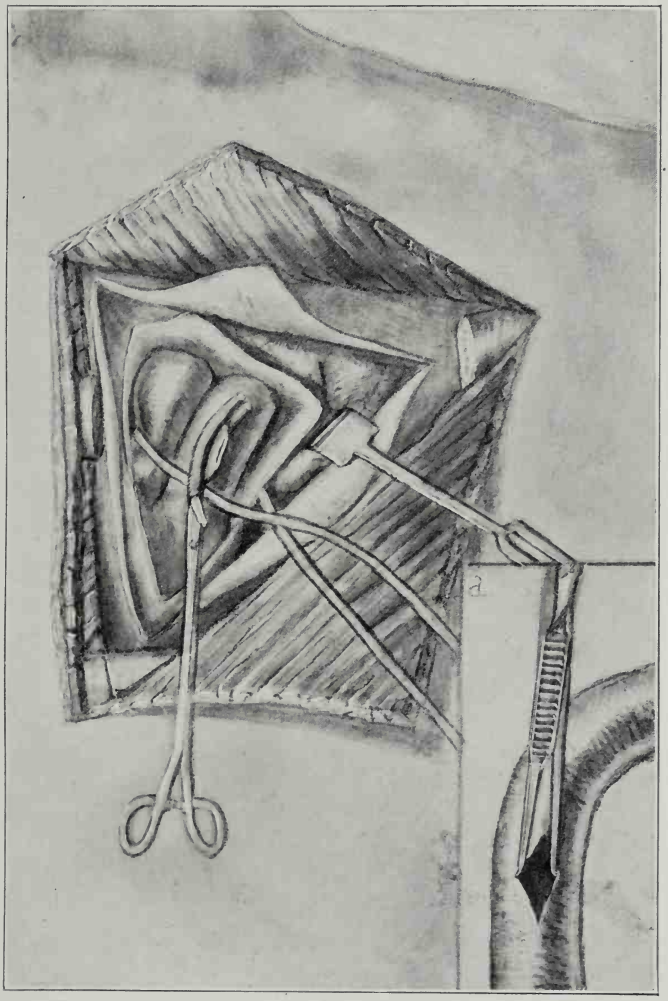

Fig. 65.—The embolus has been removed and the incision has been temporarily closed by a rubber covered clamp. It should now be sutured. Insert on lower right shows forceps (illustrated in Fig. 63) keeping the incision open and elevating it so it can be grasped by the forceps for temporary closure. (Willy Myer.)

The suddenness of the symptoms, the difficulty of the operation, the necessity for trained assistants, make it unlikely that such a procedure can be followed by success except under extraordinary conditions.

CHAPTER XI.

TREATMENT OF OCCLUSION OF THE MESENTERIC BLOOD-VESSELS; RESECTION AND TRANSPLANTATION OF INTESTINE.

Thrombosis or embolism of the mesenteric vessels is always serious whether due to a septic or an aseptic thrombus. The blood supply to the intestinal tract is practically terminal and the occlusion of even a small branch of the superior mesenteric artery usually results in gangrene of the intestine. Thrombi may begin from injury to the artery or vein and both the artery and vein may be occluded. So far as the effect upon the intestine is concerned the treatment would be the same whether the vessels are occluded by thrombi or emboli. Thrombosis occurs from local disease in the vessel wall, from injury such as a blow or a wound, from volvulus, or particularly from compression by a hernial ring as in strangulation.

One of the author's cases followed reduction of a strangulated hernia. The constriction from a strangulated hernia, particularly in a stout man, is often severe enough to injure the intima of the artery or vein and even after the intestine is returned thrombosis may occur and gangrene result. The symptoms are sometimes difficult to differentiate from those of acute obstruction as indeed obstruction sooner or later develops. At first the temperature is subnormal, but rises when peritonitis sets in. In the early stages, however, there is intense pain of a colicky nature, more or less intermittent; usu-

ally there is vomiting, and sometimes the passage of a bloody stool. Occasionally a mass may be felt in the abdomen. The abdomen is rigid and there is no distention at first. If this occurs in a child, intussusception is suspected. If in an adult, particularly after a history of trauma or hernia, thrombosis or some obstruction of the mesenteric arteries or veins must be borne in mind.

Treatment of this condition consists solely in operation. On abdominal section the affected intestine is seen to be a different color from the neighboring loops. It is dark red or even black and gangrenous. It is usually not adherent at first and is readily brought into the wound. It should be excised as promptly as possible but the greatest care must be taken to go well beyond the disease and into bowel that has a normal blood supply. If after dividing the bowel an abundant flow of arterial blood is not obtained the resection should be made at still greater distance from the disease where the blood supply is normal.

If the bowel is merely brought into the wound and drained, the contents of the small intestine empty freely on the skin of the abdomen and a marasmic and septic condition is often initiated which practically precludes any further operation and terminates fatally. If drainage is considered wise, it should be done in the loop of intestine just above the point of resection by means of a rubber catheter fixed into the intestine, after the method of Witzel. A large, soft rubber catheter will drain off fluid material satisfactorily and will give exit to the gas.

In doing a resection care must be taken to divide and tie the mesentery before the bowel is opened. In many techniques the bowel is first opened and the same scissors or knife with which the bowel is cut also divides the mesentery. This infects the triangular area at the

mesenteric border where the layers of the peritoneum separate to envelop the bowel. This area is rich in lymphatics and small blood-vessels and the instrument which has become septic by incising the intestinal mucosa promptly inoculates this area. After it has been inoculated, closing by sutures does not prevent subsequent infection here and breaking down of the stitches.

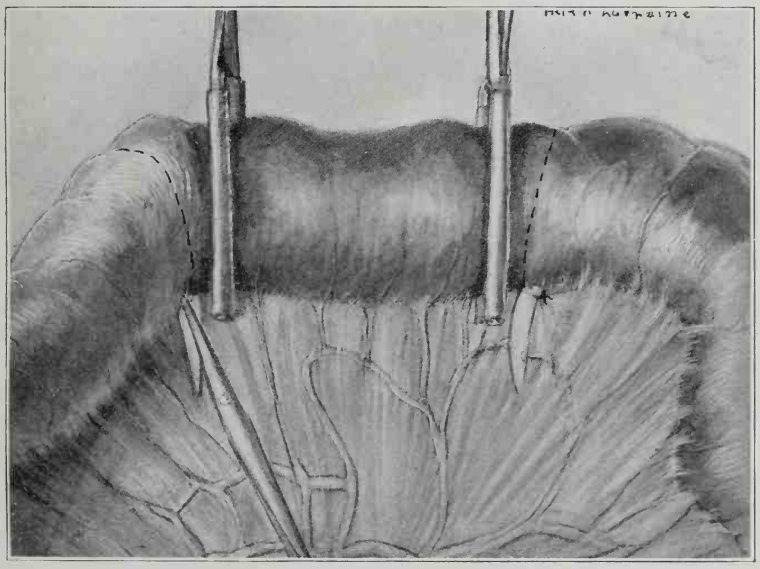

Fig. 66.—Before the bowel is divided, its mesentery is cut close to the bowel wall and the triangular space, caused by separation of the layers of the mesentery just before they cover the bowel, is clamped with a hemostat and ligated with silk or linen. This area is composed of areolar tissue rich in blood-vessels and lymphatics which absorb quickly, and even though it is closed after it has been inoculated, the germs are merely sealed in and are likely to cause breaking down of the union at this point later on. The procedure indicated in the cut obviates this and also brings together the peritoneum at this point.

In order to obviate this, the mesentery must be cut close to the bowel and this area clamped and tied; after it has been sealed in this way the lumen of the bowel may be opened (Fig. 66). The bowel is then divided and its ends cleaned with moist antiseptic gauze. The first stitch begins in the end of the bowel at the operator's right hand, about one-third of an inch from the mesen-

teric border. It is a mattress stitch and starts from the mucosa of the right bowel penetrating all coats. Then the needle is carried across to the left end of the bowel and penetrates all coats, entering on the peritoneal surface and emerging from the mucosa. It comes back in

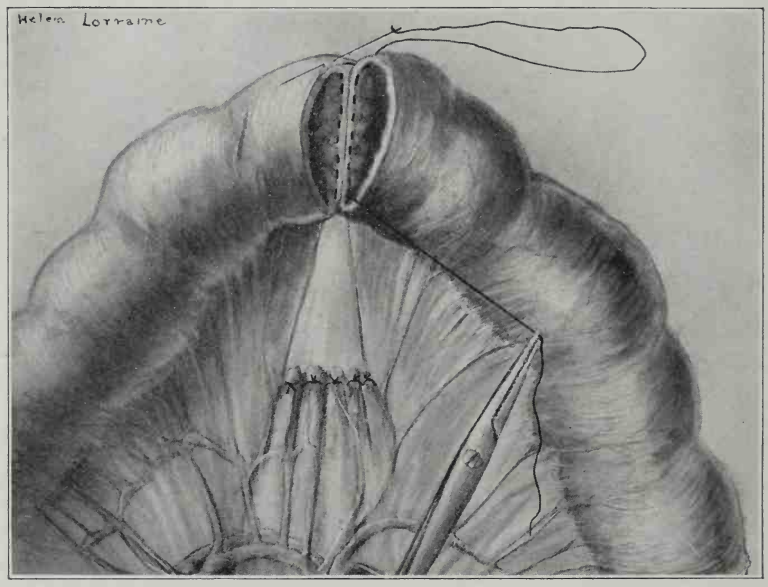

Fig. 67.—The first stitch starts in the end of the bowel at the operator's right hand about one-third of an inch from the mesenteric border. It is a mattress stitch and penetrates the wall of the right bowel from within out. The needle is then carried across to the left end of the bowel and penetrates all coats, entering on the peritoneal surface and emerging from the mucosa. It comes back in the reverse direction, entering the mucosa and emerging on the peritoneal surface, then enters on the peritoneal surface of the right bowel and emerges on the mucosa. The thread is tied, leaving an end about four inches long which is grasped in hemostatic forceps. The needle is then passed back and forth through all coats of the bowel, suturing away from the operator, and making a continuous mattress stitch. After about one-third of the circumference has been sutured, the needle emerges from the lumen of the right end of the bowel and is then thrust through all walls of the right end from within out, appearing on the peritoneal surface of the right end. The stitch is then continued as a right-angled suture penetrating all coats of the bowel.

the reverse direction, entering the mucosa of the left bowel and emerging on the peritoneal surface, entering the peritoneal surface of the right bowel and emerging from the mucosa. The thread is tied, leaving an end about four inches long which is clamped with a light

hemostatic forceps. The needle is then passed back and forth through all coats of the bowel, suturing away from the operator, making a continuous mattress stitch. Care must be taken to include a portion of the mesentery that has been tied, else it will slip back and will not be fastened by the suture. Each suture must be very snugly

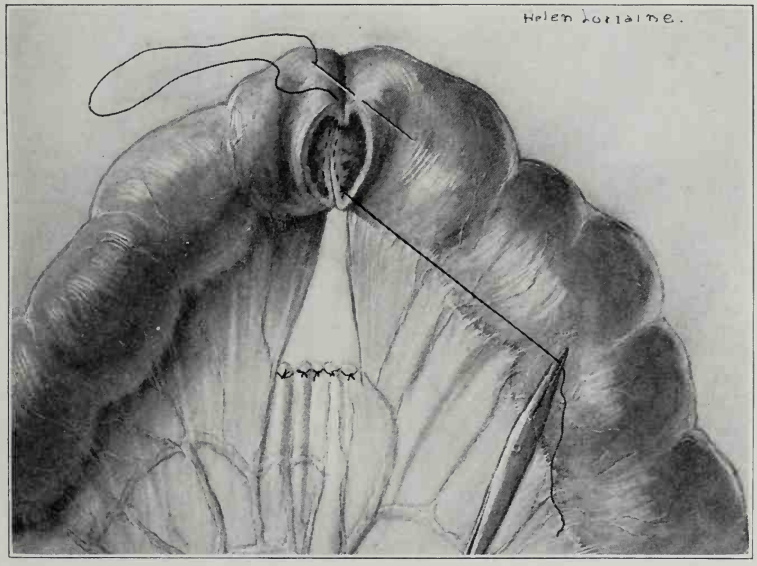

Fig. 68.—The suture is continued, inverting the bowel edge as it goes. A back-stitch should be taken at every third or fourth stitch. This is done by taking two stitches on the same side, the last one being slightly further back than the preceding stitch. This makes it impossible to draw the threads so tightly as to cause puckering and too great diminution of the lumen of the bowel.

approximated. After about one-third of the circumference of the bowel has been sutured, the needle emerges from the lumen of the right end of the bowel, and is thrust through all walls of the right end, appearing on the peritoneal surface (Fig. 67). The stitch is continued as a right angle stitch penetrating all coats (Fig. 68). Snug approximation should be made with each stitch and at about every third or fourth stitch a back-stitch should be

taken in order to prevent the thread being drawn too tightly, and so diminishing unduly the caliber of the bowel. This is done by taking two consecutive stitches on the same side, the last one being slightly farther back than the preceding stitch. It is very important to have the first third of the suture line that unites the mesenteric border drawn tightly, but after this unless the back-

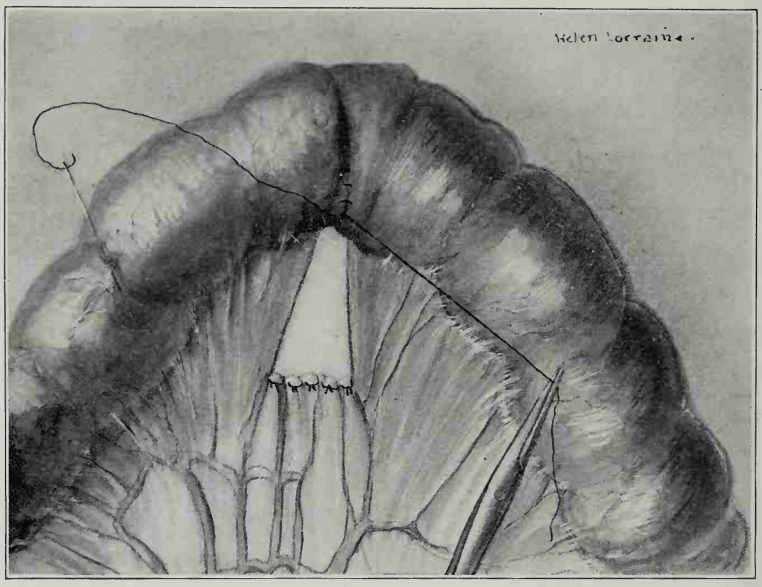

Fig. 69.—The suturing has been completed, the last stitch being taken in the left end of the bowel slightly beyond the lowest point where the original end of the thread comes out. The knot should be snug and should be tied parallel to the line of sutures so that it will sink in easily. The ends should be cut short and will disappear in the lumen.

stitch is taken at intervals, pulling the thread may diminish the lumen so much as to produce obstruction.

The suture is continued toward the operator and is carried a short distance, about a stitch, beyond the lowest point where the original thread left when the knot was tied comes out. This last stitch is in the left-hand side of the bowel. The thread is then tied firmly to the original end that is grasped in the hemostat. The knot should

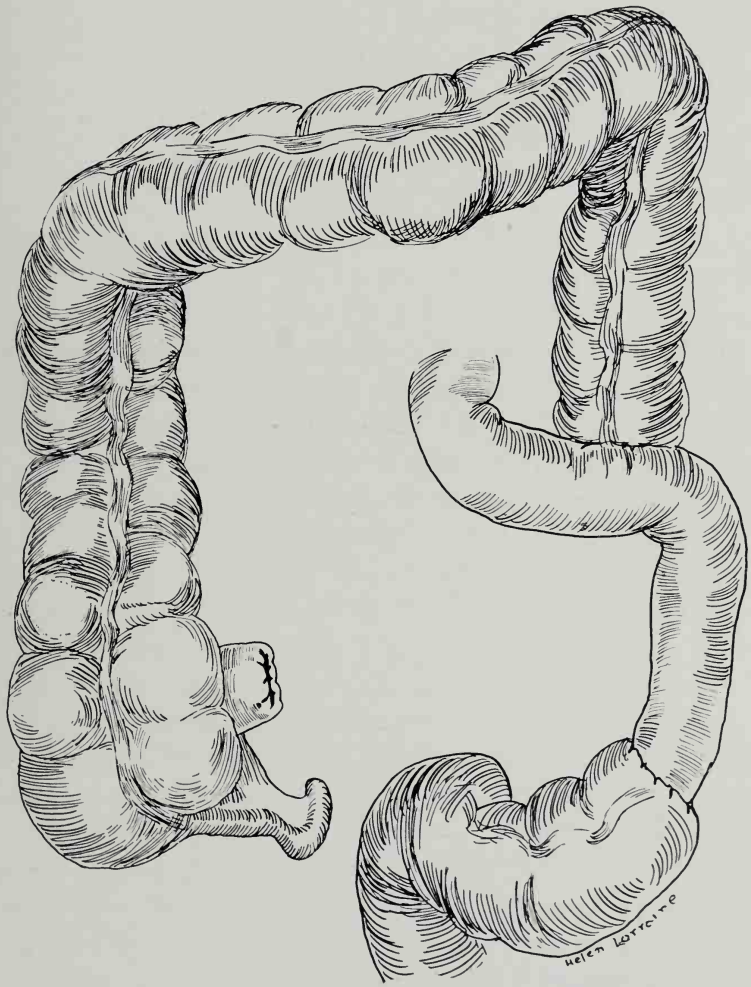

Fig. 70.—The sigmoid has been resected, the ileum cut across near the ileo-cecal valve, and its distal end closed by invagination. The ileum has been sutured to the distal portion of the sigmoid, end-to-end, and the descending colon is drained into the ileum by an end-to-side anastomosis. In this way, the defect left by excising the sigmoid is bridged over by transplanting the ileum, and the secretions from the large bowel are drained into the ileum.

be tied parallel to the line of suturing so as to sink in easily and should be tied quite snugly (Fig. 69). If a back-stitch has been taken at proper intervals, there is no danger of reducing the lumen by tying the knot too tightly. It had best be tied three times and then cut short; the ends will disappear within the bowel.

This method is simple, leaves all knots within the bowel, and there should be no leakage when it is properly used. The danger of obstruction to the lumen is obviated by placing occasional back-stitches and by properly approximating each stitch as it is made. The thread is practically all buried, leaving almost no thread exposed on the peritoneal surface, and the whole suturing can be done very quickly. All of these features are important and particularly so after a rather extensive operation such as transplantation of the bowel after resection of the sigmoid.

If the thrombosis occurs in the inferior mesentery, whether from injury or from volvulus, rather extensive gangrene of the sigmoid and descending colon is likely to result. After such an extensive excision it will be impossible to unite the ends of the bowel, and the usual procedure is to make an artificial anus or else to excise the remainder of the large bowel and do an ileo-sigmoidostomy, which greatly prolongs the operation and is often out of the question here. An artificial anus in the cecum can be made without the dangers that would attend an opening higher up in the small intestine. If the patient's condition warrants it, the ileum should be divided near its termination, united by end-to-end suture to the distal part of the sigmoid or rectum by the technique described above, and the transversed colon drained into the ileum higher up by a lateral or, better, an end-to-side anastomosis (Fig. 70).

CHAPTER XII.

ANEURISMS.

The term aneurism is applied to a cavity which communicates with circulating arterial blood. The two general classifications of aneurism are the true and the false. A false aneurism is formed from a hematoma and is equivalent to the later stages of the so-called pulsating hematoma. If in an injury to an artery, blood is poured out and a hematoma forms sufficient to prevent further bleeding, the cavity in the center of the hematoma may become lined with endothelium and the tissues in the neighborhood form a connective tissue sac. This is a typical false aneurism. A true aneurism is not a tumor in the ordinarily accepted meaning, for a tumor is new tissue that has sprung from a matrix of cells. A true aneurism is a dilatation of a previously existing vessel and is not in any real sense new tissue.

Aneurisms are divided into (1) congenital, (2) spontaneous or idiopathic, (3) traumatic, (4) embolic, and (5) aneurisms by erosion. The so-called cirsoid aneurism is not an aneurism but a true tumor, as it springs from a matrix of angioblasts and produces vessels where normally they do not occur. Congenital aneurisms are exceedingly rare and chiefly occur in persistence of the ductus arteriosus of the fetus. Idiopathic aneurism is due to disease of the arterial walls, nearly always of the middle coat. It may be initiated by a sudden rise of blood pressure or a local trauma, but these things would not in a normal vessel cause an aneurism. Spots in the

middle coat become soft and weakened from disease, or considerable areas sometimes may be similarly affected. If it is localized to a small area a sac is first formed but if the whole artery gives way, a spindle-shaped aneurism occurs. Later, these aneurisms may alter their form, so a spindle-shape becomes sacculated or vice versa. If, for instance, an aneurism that begins spindle-shaped has firm support on one side, as would be the case in the popliteal artery, the bone and solid tissue in front would eventually cause the posterior wall to give way more freely and an aneurism that began spindle-shaped becomes sacculated. If the weakening of the middle coat, which caused a sacculated aneurism extended around the artery, a spindle-shaped or cylindrical aneurism would probably result. If blood breaks through the intima it may dissect the coats of the vessel for some distance and return to the main artery at another point. This is particularly likely to occur in the aorta, and sometimes this new channel is lined with endothelium. The idiopathic aneurisms are by all means most numerous. Traumatic aneurisms are supposed to be due to direct injury of the arterial wall and are very likely to be false aneurisms, or arteriovenous aneurisms.

Various parts of the sac occasionally give way and one aneurism may be engrafted upon another, so producing a multilocular sac.

Embolic aneurisms are due to an embolus, which may or may not be infectious. The embolus may consist of a foreign body that has lodged in some portion of an artery and causes dilatation either mechanically or from infection.

Erosion aneurisms are practically abscesses or localized deposits that form along the course of an artery and weaken the arterial wall, eventually communicating with

the artery. These should be classed under false aneurisms. A true aneurism is practically always of spontaneous type and has one or more coats of the artery in its sac. The middle coat is always lacking except in the very beginning of the aneurism when some trace of the media may be seen.

The sac of an aneurism may be cylindric, fusiform, or sacciform, and one of these forms may change into the other either on account of the anatomical surroundings, as has already been mentioned, or on account of the location near a joint, or from the change of direction of the blood stream. The location of an aneurism has a great deal to do with its shape. Aneurisms of the aorta, where the viscera of the thorax or abdomen offer but little resistance, may attain large size. Aneurisms developed in dense tissue grow in the direction of least resistance. The sac of an aneurism is lined with endothelium, and frequently contains an old white blood clot that has been partly or fully organized and may practically form another layer of the sac. Sometimes a number of these clots occurs. It was formerly thought that white clots were different from the softer or red clots, but there is usually a gradual transition from the red clot to the white clot. The red clot becomes partly organized, its coloring matter is absorbed, the fibrin contracts, its substance is penetrated by blood-vessels, and it forms a distinct layer.

Occasionally, but not often, the sac is completely filled with clots which organize and cure the aneurism. Such an occurrence is so infrequent as to be counted a surgical curiosity. The tendency of an aneurism is to grow until rupture occurs or until death results in some other way. In the abdominal aorta three-fourths of the aneurisms result fatally by rupture. Death may also be caused by

pressure upon the lungs or trachea, by infection and sloughing of the sac, or by gangrene in the extremities, but the most usual termination is by rupture.

The direct cause of the vast majority of aneurisms is, as has already been stated, a disease of the middle coat of the artery. This form of arteriosclerosis is one of the handicaps of civilization. No lower animal has aneurism except the horse which sometimes has a form of embolic aneurism from a parasite, *strongylus armatus*. In fact, it is practically impossible to produce experimentally aneurisms in the lower animals that correspond to the idiopathic aneurism in man. Some pathologists have created aneurisms in animals by the injection of suprarenal extract or other toxic substances that cause degeneration of the middle arterial coat. This has been done in rabbits, but under ordinary conditions the idiopathic aneurism is unknown in the lower animals. The influence of civilization is best shown by the fact that in slavery days aneurisms in the negroes were almost unknown, whereas now it is four times more frequent in negroes than in the white race. More than seventy per cent of aortic aneurisms are due to syphilis. Syphilis combined, as it often is, with alcoholic excesses and sometimes with hard manual labor, practically constitutes the sum total of the direct causes of idiopathic aneurisms. As Osler has said, Venus, Bacchus, and Hercules are the etiologic trinity of aneurisms. Syphilis and alcohol cause degeneration of the middle muscular or elastic coat and exertion or undue pressure from any cause produces a giving away at this point, similar to what the automobilist calls a blow-out.

As might be expected, the main artery, which has the chief burden of blood pressure to bear, is the most frequent seat of aneurism. According to Matas in one hun-

dred and seventy-two cases of aneurism compiled by Holcombe, they were distributed as follows: in the thoracic aorta, seventy; in the abdominal aorta, thirty-six; popliteal, twenty-one; femoral, ten; innominate, nine; subclavian, eight; common carotid, five; external iliac, two; brachial, two; axillary, two; and one each in the vertebral, ulnar, radial, celiac axis, splenic, occipital, and temporal artery.

It is interesting to note that after the aorta, aneurisms of the popliteal are most frequent. This is due not to the unusual pressure in this vessel, but to the trauma from the frequent flexion and extension of the knee.

Aneurism in young children is practically unknown. It occurs most often between forty and fifty years and is not infrequent in old age. As we would expect, it is chiefly a disease of the male and in the proportion of about two to one. After the fifth decade, however, it seems to occur equally in both sexes. The etiologic factors that have already been mentioned will readily suggest why it is chiefly a disease of man. The size of an aneurism depends partly upon its location. An aneurism may attain enormous proportions in the thorax or abdomen, whereas in the brain and particularly in the region of the fourth ventricle, a very small aneurism may be fatal.

Symptoms and Signs.

Usually an aneurism is readily recognized, but sometimes when numerous clots have been deposited within the sac its diagnosis is exceedingly difficult. Before the advent of the X-ray a mistake was by no means rare. Such surgeons as Dupuytren, Esmarch, Pirogoff, and many others have made disastrous errors in the diagnosis of this condition, which, however, would hardly be justi-

fiable at the present time. The history of the case is always of great importance and should be carefully taken wherever there is a possibility of aneurism. A history of syphilis, or the presence of a positive Wassermann, in connection with any growth along the blood-vessels would make a diagnosis of aneurism very much more probable. The age of the patient, race, sex and habits are also suggestive. The history of the growth, the presence of pain, the presence or absence of a leukocytosis, particularly a high count of polynuclear white cells, may serve to differentiate between an abscess and an aneurism.

The physical examination to be made depends to a large extent upon the location of the aneurism. If in the thoracic aorta it attains a large size before the sac can be palpated. Here, however, the physical signs should give some indication, for there is dullness on percussion and possibly the presence of a thrill that may be felt. Bronchial breathing, shortness of breath, visible enlargement of the veins of the neck and arms, sometimes swelling of the arms and neck, pain referred to the intercostal nerves, hoarseness, cough, or even paralysis of the left vocal cords caused by pressure on the recurrent laryngeal, disturbances from pressure upon sympathetic nerves as contraction or dilatation of the pupil, sometimes difficulty in swallowing and frequently trachial tugging are the chief signs and symptoms of a thoracic aneurism. Trachial tugging is best brought out by extending the head and neck, when the larynx is seen to be pulled upon by the trachea at each beat of the heart. Probably the most important diagnostic aid in thoracic aneurism is the X-ray. The refinement of modern skiagraphy can show the presence of a thoracic aneurism of even small size and should always be appealed to in making a diagnosis of this condition.

The signs and symptoms of aneurisms in other portions of the body depend to some extent upon the location. In an aneurism situated in one of the extremities or in the neck there is a difference in the pulsation of the artery distal to the aneurism when compared with the corresponding artery in the other limb or on the other side of the neck. This is due to the fact that a great deal of the pressure in the blood stream is taken up in the aneurism and the artery distal to it has lower pressure than the corresponding artery on the other side of the body. The beat is usually somewhat delayed for the same reason. Frequently the pressure of the aneurism on the veins in the neighborhood will produce edema or swelling distal to the aneurism and also enlargement of the veins. Occasionally the venous collateral circulation is made evident by the dilated veins under the skin. If, however, pressure upon the vein is not too great there is but slight dilatation of the superficial veins as the venous flow, even when partially obstructed, can return the diminished arterial supply unless the pressure in the artery is so interfered with by the aneurism that the blood cannot be properly forced through the vein. Pressure upon nerves often causes pain and sometimes muscle spasm and trophic disturbances. There may even be erosion of the bone which can be demonstrated by X-ray. As a rule, however, aneurisms in the extremities grow in the direction of least resistance and that wall which is opposed by solid bony tissue will be supported and the aneurism will be forced to enlarge in other directions. Sometimes infection of the sac occurs. This seems peculiarly liable to happen in the external iliac and upper femoral arteries and has been the cause of many disastrous mistakes. The inflammatory thickening of the tissues together with the increased coagulability of

the blood, which may cause deposit of clots in the sac, frequently obliterates any pulsation that normally would be present. The signs of inflammation and probably the actual presence of pus may lead the operator to believe there are several pockets, and in his effort to be thorough the aneurism may be opened. With the history of the case and a good X-ray picture, such mistakes should be very infrequent in modern times.

The physical, local signs of aneurism are expansile pulsation, thrill, and bruit. Pulsation can be detected by sight and by palpation. An aneurism, the walls of which are too thick for pulsations to be distinctly expansile, should be distinguished from a solid tumor, and sometimes from an inflammatory mass that rests upon the artery and transmits pulsations. The character of the expansile pulsation can usually be told by resting two fingers close together upon the enlargement and observing that they are not only lifted up but that they are to some extent separated at the height of each pulsation. A more accurate way of determining this would be to mark two points on the skin over the enlargement and test the distance between them with calipers during systole and during diastole.

A thrill is often felt by palpation with the fingers or with the whole hand. It is not so marked in aneurisms as in arteriovenous aneurisms. Bruit is detected by auscultation and is heard most distinctly over the growth, though it may be transmitted along the course of the artery for some distance. This is not due to vibration of the opening, as was formerly thought, but the sound is made by the current of blood.

Direct pressure on an aneurism usually diminishes it, but when the pressure is removed the aneurism returns to its original size. All of the characteristic signs are

abolished when the main trunk of the artery between the aneurism and the heart is compressed.

Treatment.

The treatment of aneurisms is divided into medical and surgical. Medical treatment consists in the direction of diet, and personal hygiene, together with the administration of such drugs as create a tendency to clotting in the sac. This is supposed to be obtained by diminishing the blood pressure on the one hand, and by increasing the coagulability of the blood on the other.

Medical treatment was first introduced by Valsalva and Albertini in 1728. According to the original method it consisted of absolute physical and mental rest, and repeated bleedings. In this manner the blood pressure was reduced and the coagulability of the blood increased. Very little fluids were given and only 125 grams of food were permitted in a day. This treatment has been made much less severe and now ordinarily consists of rest in bed and a light diet, without bleeding, together with the administration of such drugs as increase the coagulability of the blood or lower the blood pressure. Iodide of potash appears to be the most effective; nitroglycerine and the nitrates are used. Calcium chloride is given in doses from ten to twenty grains three times a day with the idea of increasing the coagulability of the blood.

The injection of gelatin has received a great deal of attention. Great care should be taken in sterilizing the gelatin, as not infrequently cases of tetanus have been caused by imperfect sterilization. While at one time it was extensively used in thoracic aneurisms, it is now but seldom employed. A good many observers, however, have reported very striking results. Ennion G. Wil-

liams [1] reported two cases of thoracic aneurism in which he used gelatin with temporary benefit in one case. He recommends injecting fifty cubic centimeters of a five to ten percent solution in water, great care being taken to sterilize the gelatin thoroughly. The time of coagulation of the blood decreased from two and a half minutes before injection to a minute and a half after injection in one of his cases. Bollenstein, in 1904, reported forty-six percent of favorable results in 126 cases. These, however, do not necessarily mean cures.

The action of gelatin seems to be chiefly in the destruction of white blood cells, thus liberating the elements that go to form fibrin ferment. It may be administered as a ten percent solution in ordinary salt solution giving fifty cubic centimeters, or as a three percent solution in Locke's fluid, injecting 250 cubic centimeters in the lumbar or glutial regions every five or six days until twenty injections are given. This may be continued over a period of several months.

The diet recommended in these cases is, for breakfast, two ounces of bread and butter and two ounces of milk; for dinner, three ounces of meat, two ounces of bread and potatoes, and four ounces of water; for supper, two ounces of bread and butter and two ounces of tea. This may be varied to some extent, particularly in the line of decreasing meats and tea. Milk may be substituted for meat.

The symptomatic treatment consists in the administration of drugs that relieve pain, such as morphine and atropine or codein, or such remedies as aspirin. Compresses of lead water and opium or an ice bag placed over the skin, which should be fully protected, often afford some relief.

[1] Old Dominion Medical Journal, August, 1903.

Surgical treatment includes various methods, such as wiring, electric puncture, direct and indirect compression, ligature, incision, obliteration of the sac, and excision of the sac alone or combined with the substitution of a segment of vein.

We will first consider the methods particularly applicable to aneurisms of the aorta as these aneurisms cannot be reached by the direct attacks employed elsewhere. "Needling" was advised by McEwen in 1890. The method is quite uncertain, though McEwen reports satisfactory results. It consists of the introduction into the sac of a long, fine needle which scratches thoroughly all of the lining of the sac. This is followed by the disposition of fibrin and according to McEwen the fibrin thrown down after needling is peculiarly firm. The operation, however, has not been adopted by many surgeons.

The introduction of wire into an aneurism was first done by Moore, of London, in 1864. It has been widely used, particularly in connection with the modification by Corradi, in 1879, of passing a galvanic current through the wire. Finney, of Baltimore, has had very favorable experience with it and reports several cases much benefited and some apparently cured. Finney recommends the wire originally proposed by Hunner, which consists of a silver alloy containing seventy-five parts of copper to 1,000 parts of silver. This wire is wound tightly on a wooden spool, in order to make it coil, and should be of such size as will readily pass through the ordinary aspirating needle. The needle is insulated with a coat of the best French lacquer to within a short distance of its point. This prevents an electrolytic burn that might be the seat of a subsequent hemorrhage. Under local anesthetic the needle is inserted into the skin which is drawn to one side so when the needle is removed the opening in

the skin is not opposite the opening in the sac. Finney uses ten feet of wire, claiming that a larger amount may prevent the contraction of the clot in the sac. The needle is inserted slowly until arterial blood appears in spurts through the needle. The end of the wire should be engaged in the lumen of the needle before the needle is inserted. At first a small amount of blood will spurt around the wire. The wire is then threaded through into the aneurism, care being taken that no portion of the needle that is not protected with lacquer comes in contact with the skin. The positive pole of a galvanic battery should then be connected with the wire, a negative pole being placed at the patient's back. This is important as the negative pole to the wire will cause disorganization of the clot rather than hasten its formation. The current, according to Finney, should be not greater than seventy-five m.a., but should be continued at least an hour. In abdominal aneurisms, the aneurism should, of course, be fully exposed and the viscera packed away. This is done under local anesthesia. After the current has been passed at least an hour in thoracic aneurisms the needle is slowly removed, twisting it somewhat in order to withdraw it gradually. The skin is depressed around the wire and the wire cut flush with the skin. The skin is then pinched up and the end of the wire will disappear under the skin. If the skin has originally been drawn to one side, there is no direct communication between the hole in the skin and that in the sac.

Aneurisms of the aorta should first be carefully studied with the X-ray before being subjected to wiring. A diffuse dilatation or a spindle-shaped aneurism obviously cannot be treated by such a measure, which should be reserved for the distinctly sacculated type. Attempts have been made to cure aneurisms of the abdominal aorta

by ligature, and the abdominal aorta has so far been ligated for various causes, chiefly for aneurism, about twenty times with fatal result in each case. In some abdominal aneurisms the metal band introduced by Halsted seems indicated. By this means the circulation can be greatly diminished though not entirely obliterated, and after collateral circulation has been sufficiently established the band may be removed and a ligature applied. If, however, important arteries, such as the renal or the coeliac axis, arise from a prominent portion of the sac the case would seem utterly hopeless, as any method that obliterates the sac would, of course, occlude these arteries with the necessity of a fatal result.

In the treatment of aneurisms of the extremities it is important to develop the collateral circulation to as great an extent as possible before any attempt is made to excise the aneurism or to close the sac. This may be done by hot packs around the limb several times a day, extending over a period of a half to one hour at a time. Digital pressure on the artery or pressure by a special apparatus may also be used. The circulation should be tested, as suggested by Matas, by applying a firm Esmarch bandage from the extremity of the limb to the trunk. The main artery is then compressed, the Esmarch removed, and note made of the returning circulation which is carried on collaterally. In the leg a hyperemic flush extends quickly to the knee, but may go much more slowly or not at all to the foot. If the flush does not reach the ankle, operation should be postponed and treatment with hot packs or local compression of the artery is instituted until collateral circulation has been satisfactorily established. The most serious objection to this method of testing is that it is inapplicable in negroes or in people with a very dark skin.

A method of treatment in many instances and a most satisfactory means of developing collateral circulation in all cases is the use of a metal band, first devised by W. S. Halsted. The original Halsted band has been further modified by Matas and by Halsted and in its simplest form consists of a small band of aluminum, about one-fourth of an inch wide, which can be rolled around the artery with the fingers. Halsted originally devised a special instrument for this. The band is not rolled tightly enough to occlude the artery but merely to an extent that will reduce its circulation to a minimum. In this manner collateral circulation is developed, while at the same time there is a small current through the main artery. After a week or two the band is removed and the artery either occluded by a tight ligature or the aneurism obliterated by the operation of Matas, with but little danger of gangrene.

Mayetti [2] describes a method of occluding large vessels by strips of fascia or tendon instead of metal bands. The fascia is taken from the animal or individual and constitutes an autograft. Mayetti recommends fascia lata. A strip is placed around the vessel and fastened with a silk suture. In his experimental work, the artery could be reduced to one-third of its natural size without signs of thrombosis.

Matas and Allen in some excellent experimental work demonstrated the feasibility of partial obliteration of the aorta in dogs. The results of their experiments were read before the American Surgical Association in May, 1913, (Annals of Surgery, September, 1913). They show that the aorta, if healthy, can be partially occluded by infolding it with layers of sutures. This, of course, cannot be done except in healthy blood-vessels which unfortu-

2 Policlinico, Rome, January 12, 1913.

nately is the exception rather than the rule near aneurisms.

Scalone [3] gives a method for partially obliterating blood-vessels by placing sutures with a curved needle through the superficial layers of the blood-vessel in such a manner that the vessel is infolded just as the pylorus is sometimes infolded. The external tissues are brought firmly around the vessel to maintain and support the obstruction.

Compression is recognized as one of the oldest methods of treating aneurisms. While various appliances have been used they have not been quite so satisfactory as digital compression properly applied. It requires a number of assistants who can relieve each other from time to time. The skin where pressure is to be made is covered with French chalk. Each assistant is instructed as to the amount of pressure necessary, the direction in which it must be made, and the manner of changing from one assistant to another, so at no time during the treatment is the artery without compression at or about the same point. The femoral artery below Poupart's ligament is the most favorable location for digital compression. Each sitting lasts four hours. Sometimes one sitting will result in a cure, but usually ten or even twenty sittings are necessary. This method is unsatisfactory and uncertain in comparison with modern methods and is by no means free from danger of gangrene.

The elastic compression of Reid consists of bandaging the limb by means of an elastic bandage up to the aneurism and then skipping the aneurism, but bandaging the limb above it. In this way the blood is shut off above and below the aneurism and clotting is often produced. The bandage, however, should not be left on longer than

3 Policlinico, September, 1913.

an hour and a half and in elderly people half this time is much safer. According to Delbet, this treatment leads to gangrene twice as often as digital compression.

Extreme flexion has been suggested by a number of surgeons, but is often called the method of Hart. It is applicable in the treatment of aneurisms developing in the popliteal region, in the groin, or in the elbow. It consists of forced flexion which must be maintained about fourteen days. It is exceedingly painful and cures only about one-third of the cases.

The classical methods of using the ligature for the cure of aneurism have been long established. The operation of Antyllus has been practiced since the second century of the Christian era, and has on the whole given exceedingly satisfactory results. It consists of ligating the artery close to the aneurism, both centrally and distally, and then incising the sac (Fig. 71). In preantiseptic days the suppuration following this method made the mortality high, but in spite of that the percentage of cures has been gratifying.

Anel's method, first used in 1710, is ligating the artery centrally but as close as possible to the sac. In preantiseptic days where suppuration was a rule, secondary hemorrhage was frequent. It was thought this was partly due to the fact that the artery near the sac was very likely to be diseased; so John Hunter established a new principle of ligating, in 1785, by applying the ligature centrally, but at some distance from the aneurism. In this method branches are given off from the main artery between the ligature and the aneurism. It is still used to some extent but has many disadvantages. First of all, it assumes that the artery is less diseased at a distance from the aneurism than close to it. This is by no means always true. Secondly, the liability to gangrene

is increased, because if the sac is occluded by a clot there will be two obstructions to the current instead of one, the obstruction at the site of ligature and another farther

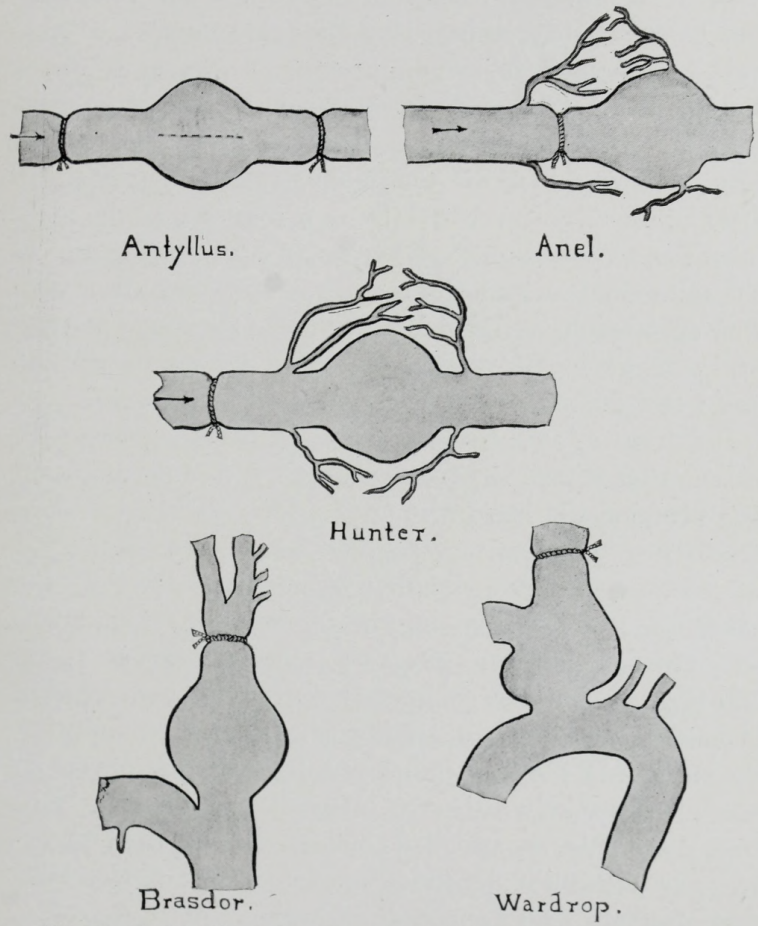

Fig. 71.—Diagram illustrating the various methods of ligation for aneurisms.

down where the aneurism is closed by clots. Then the collateral circulation between the ligature and the sac is greatly diminished and the blood has to pass through two sets of collateral branches, one from above the ligature

to the vessels between the ligature and the aneurism and one from this last set to the vesesls below the aneurism, in order to maintain the nutrition of the limb. If, however, the collateral circulation is free, the aneurism may not be sufficiently occluded by clots and no cure will result. With modern technique and absorbable ligatures the operation of Anel is far superior to that of Hunter.

Brasdor instituted the method of distal ligation in 1798, ligating distally the main trunk. Wardrop, in 1825, applied ligatures distally to one or two of the main branches of the artery. This was used in aneurisms of the innominate where the carotid artery was often tied. The application of a ligature immediately above and below without opening the sac is called Pasquin's method and was first applied in 1812.

Ligation on each end and close to the aneurism with extirpation of the sac has been known as the operation of Purmann, who used it in 1680. This method has been recently very extensively employed on the continent. It is necessary to have complete hemostasis either by the tourniquet, or by clamping, or by temporary ligatures. Often large collateral vessels open into the sac, so a central ligature may not completely control the hemorrhage. It is also important to preserve the vein in extirpating the sac, for if the vein is injured or ligated, gangrene is much more likely to occur. Bleeding should be controlled by sutures, which do not go deeper than necessary, as packing if depended upon to stop bleeding may also interfere with the collateral circulation.

Gangrene occurs in mass or in patches merely involving small localized areas. It is particularly important to follow the usual after-treatment, to stimulate the heart by drugs and by the introduction of salt solution by rectum. The whole limb should be well wrapped in cotton

and moderately elevated in order to secure venous drainage, but not too much elevated as this might interfere with the arterial circulation. Hot air ovens may be used. After the wound has begun healing, hot baths and massage with active and passive motion are instituted.

Ligation with extirpation of the sac compares very favorably in results with simple ligature, as it has a somewhat lower mortality in a large number of cases than the Hunterian method of ligation, and the dangers of gangrene are about the same.

The greatest improvement in the treatment of aneurisms in modern times is the operation of Matas, which was first performed by him in 1888, on a brachial aneurism that had not been cured by either proximal or distal ligature. The operation is subdivided into three different types, though the principle is the same in each. The fact that extirpation of the sac, and that the Syme operation in which the artery is ligated within the sac, is followed by a comparatively low mortality and a high rate of cure makes it quite evident that the nearer the ligature is placed toward the sac, other things being equal, the better the results will be. The objections to extirpation are obvious. The operation is not only difficult and involves the enucleation of considerable tissue, but there is a likelihood of injury to the veins or nerves, and, most important of all, the tissues enucleated often carry collateral vessels that are highly important.

The three types of the operation of Matas are obliterative endo-aneurismorrhaphy, restorative endo-aneurismorrhaphy, and reconstructive endo-aneurismorrhaphy (Fig. 72). The obliterative type may be used in any form of aneurism, but it was particularly designed for cases in which there are two openings in the sac some distance apart, or when the sac is peculiarly friable.

Hemostasis is obtained by a tourniquet if possible, or if this is impracticable by Crile, Matas or the author's clamps on the artery and its main branches both above and below the sac. The sac should not be dissected out, so wherever a tourniquet can be used instead of a clamp it should always be preferred. By bearing in mind the principle on which the operation is founded—conserving every possible collateral branch in the sac and surrounding tissues—the operation can be carried out more intelligently. After the tourniquet has been applied an ample incision is made through the skin over the aneurism. If it is impossible to place the tourniquet, the vessel is exposed centrally and peripherally a few inches from the aneurism, and clamps applied, as mentioned above. The sac is then opened without separating it from the surrounding tissue and clots are thoroughly removed. A suture of chromic or tanned catgut in a small, round, curved needle is passed around the openings of the artery taking care to tie the openings snugly but not using too much force as the suture may cut out. The sac is searched for other openings of collateral arteries or branches and these are also closed. Then the sac is obliterated by rows of sutures of chromic or tanned catgut, the first row running preferably from one arterial opening to another. After this has been finished another row is placed. In intraperitoneal aneurisms the peritoneum is sutured so as to cover the raw surface. The manner of treating the sac after the two tiers of obliterative sutures have been placed depends largely upon the condition of the sac and must of necessity be left to the judgment of the surgeon, as in plastic work. The essential features are to close the arterial openings into the sac and to place at least two rows of continuous chromic or tanned catgut, obliterating the sac as far as possible from one of the main arte-

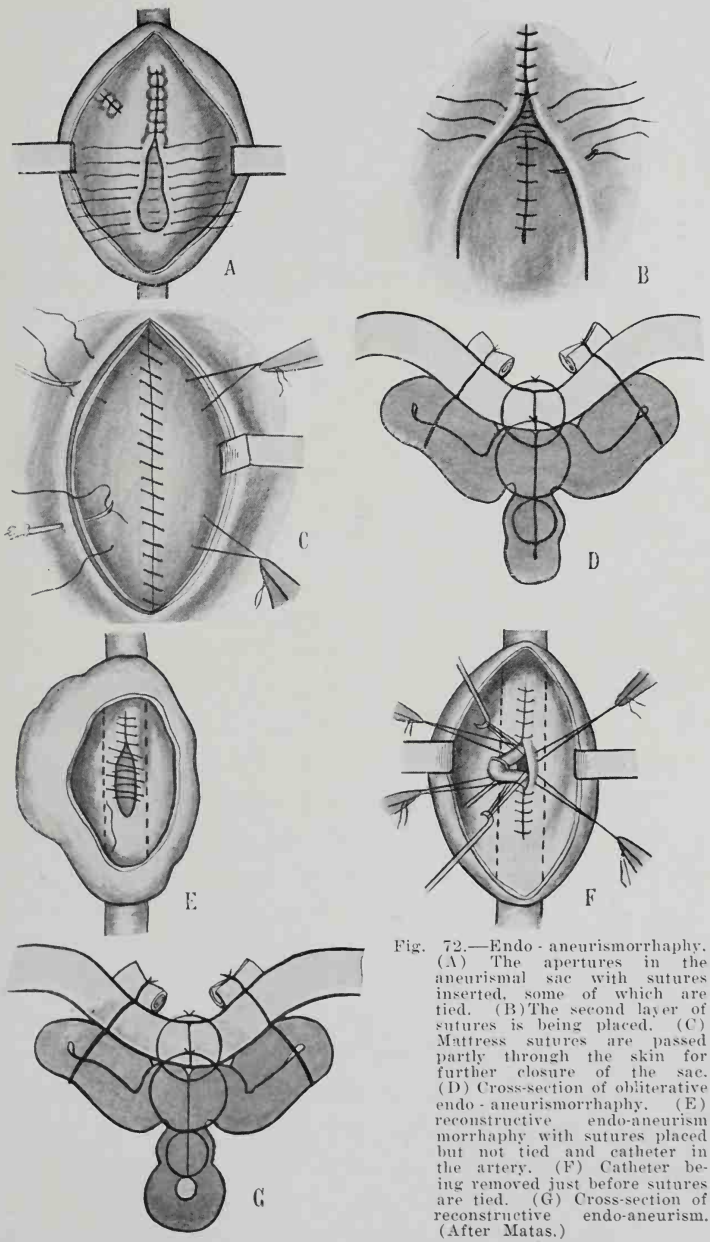

Fig. 72.—Endo-aneurismorrhaphy. (A) The apertures in the aneurismal sac with sutures inserted, some of which are tied. (B) The second layer of sutures is being placed. (C) Mattress sutures are passed partly through the skin for further closure of the sac. (D) Cross-section of obliterative endo-aneurismorrhaphy. (E) reconstructive endo-aneurism morrhaphy with sutures placed but not tied and catheter in the artery. (F) Catheter being removed just before sutures are tied. (G) Cross-section of reconstructive endo-aneurism. (After Matas.)

rial openings to the other. After this, the recesses of the sac are folded upon themselves if possible, or sutures are carried through a double thickness of the sac and tied in the margin of the wound, or else brought out through the skin (Fig. 72). All dead spaces should be obliterated and the wound closed without drainage. The blood current is gradually turned on before the skin is sutured and the infolded sac is pressed upon. Usually but little if any oozing occurs, though if it is marked the tourniquet should be reapplied and the leak stopped by additional sutures. The smooth membrane lining the inside of the sac is vascular endothelium and requires no freshening or injury to heal, but merely snug approximation just as in peritoneum.

Restorative endo-aneurismorrhaphy is applicable when the sac is tough and resistant and when there is only one opening. In other words, when the aneurism springs from one side of the artery and the whole of the artery's circumference is not involved. This does not occur very frequently. In such cases the opening is sutured either by surrounding it with a purse-string suture or by whipping it over with a continuous stitch. The rest of the procedure is identical with the obliterative method.

Reconstructive endo-aneurismorrhaphy is recommended by Matas in cases in which the two openings are close together, where there is but little atheroma, and where the sac is tough and holds sutures well. The sac is cleaned of clots and washed out with salt solution and the region of the two openings is anointed with white vaseline. Matas recommends that a soft rubber catheter well anointed with vaseline and which fits snugly into the arterial openings be inserted and interrupted sutures of chromic catgut be placed at close intervals over the

catheter. After the sutures have been placed the catheter is withdrawn and the sutures tied snugly. The rest of the sac is obliterated as in the other methods.

In all of these methods care should be taken not to take a deeper bite with the sutures than is necessary to secure a firm hold. The needle may wound the accompanying vein or nerve, or if inserted too deeply, may occlude some collateral vessel.

It is doubtful if reconstructive endo-aneurismorrhaphy does not sooner or later become obliterative. The fact that in several instances thrombi formed after the reconstructive operation which later were dislodged and acted as emboli, is also a serious objection to this method. In the light of modern blood-vessel suturing, we can hardly expect the reconstructed artery to remain patent. In experimental work under the best conditions with comparatively healthy blood-vessels and using the finest sutures of silk and the finest needles, it is impossible to avoid obliteration in a considerable number of cases even after some experience in this work. This being the case, we can hardly expect suturing with comparatively coarse needles and catgut in tissue that is diseased to reproduce a permanently patent artery. If there is merely a small opening the restorative method may be indicated, but the eventual result will probably be better if the obliterative method is always used instead of the reconstructive type. The only advantage in the reconstructive operation is the fact that for a short time blood flows through its natural channel and the consequent strain upon collateral circulation will not be so great. This advantage, however, seems offset by the dangers of sudden emboli from the breaking loose of the thrombus, by the fact that sooner or later the channel in all probability becomes obliterated, and by the further fact that recurrences are

much more common after the reconstructive than after the obliterative method.

Matas has collected statistics which prove beyond doubt that wherever endo-aneurismorrhaphy can be applied it is far more satisfactory than either ligature or extirpation; not only is the mortality rate less but gangrene is exceedingly rare.

Extirpation of aneurisms has been done in a few instances with direct suture of the artery by the end-to-end method. This is only applicable where the site of the aneurism involves a very short section of the artery and where the ends of the artery are comparatively healthy. It has been done by Lexer, Stich, and Enderlen in popliteal aneurisms. The limb is flexed and kept in this position for several weeks by plaster of Paris. After the sixth week the knee may be gradually extended. This method has, of course, a very limited application.

The ideal treatment of aneurism is to excise the sac and at the same time to restore the arterial channel. This is accomplished by substituting a segment of vein. The vein that accompanies the artery has been used, though it would be much better to utilize some other vein. Obviously when the direct circulation is deficient on account of the aneurism and collateral circulation is poor, closing the main artery by ligature or obliteration of the sac—even by the excellent method of Matas—is fraught with great danger and the indications are if possible to reëstablish the circulation by the ideal method. In a diseased artery, arterial sutures would not seem to be satisfactory, and it is certainly more desirable to suture healthy arteries in traumatic aneurisms than the diseased vessels of spontaneous aneurisms. However, the brilliant case of Lexer, already referred to above, in which he excised an aneurism involving a portion

of the external iliac and femoral arteries and sutured into the defect a segment of the saphenous vein with perfect success, shows the great possibilities of this operation.

If success is to be attained in suturing diseased arteries the best possible technique should be used. As already pointed out, it is not likely that reconstructive endo-aneurismorrhaphy in which comparatively coarse needles and catgut are used, will result in a permanently open channel. Certainly in experimental work such technique would invariably be followed by thrombosis even in healthy arteries, and in diseased arteries we have no right to expect better results. It is practically impossible, however, to use the technique of arterial suturing in the bottom of a sac where the tension on the stitches must be considerable, but after the sac is excised a segment of vein can be sutured into the ends of the artery with the regular technique for end-to-end suture. While there is some danger of the segment becoming occluded by thrombus, it would seem for the reasons mentioned and particularly in the light of Lexer's case that if it is necessary to reëstablish the current of the blood, it should be done not by the reconstructive method of Matas, but by excision of the sac and suturing into the defect a segment of vein. Reversing the circulation and then excising the aneurism has also been tried. This has none of the advantages of transplantaion of a vein.

Treatment of Aneurism of Special Arteries.

Aneurisms of the thoracic aorta are by far the most frequent kind of aneurisms, which would naturally be expected from the strain to which this great vessel is subject. The proper treatment is the medical treatment that has already been outlined, though in sacculated tho-

racic aneurisms the Moore-Corradi method may be used. The technique as employed by Finney is probably the most satisfactory (page 221). A thorough examination by X-ray should be done before this operation is attempted. The average course of a thoracic aneurism is a little more than a year. There has been one effort to cure a thoracic aneurism by ligating the aorta. This was done by Guinard, of Paris, in 1904, the chest being opened posteriorly by an osteoplastic flap and a ligature placed on the thoracic aorta just below the end of the arch. When the ligature was tightened, pulsation in the femoral artery stopped and the lower part of the body became pale and cold, but in a few minutes the circulation was reëstablished through the intercostal and other vessels. However, the blood pressure through collateral circulation was not sufficient for the renal arteries and the patient died.

Aneurisms of the abdominal aorta are scarcely amenable to other direct treatment than the Moore-Corradi method. If the aneurism is above the renal arteries or involves the mesenteric, its obliteration will necessarily result fatally on account of interference with the function of the kidneys or from gangrene of the intestines. Below the inferior mesenteric artery, the outlook seems more hopeful, but the results are practically equally as disastrous. Of about twenty cases of ligature of the abdominal aorta none has been successful. The strain thrown upon the heart by the increased blood pressure after such a ligature is enormous and this high pressure and a competent heart are essential to the proper establishment of collateral circulation. Most of these patients have hearts that are far from competent and even in healthy animals, ligation of the abdominal aorta usually results in a cardiac death. In a case of Keen's the ab-

dominal aorta was ligated and the patient lived until the forty-eighth day. Even if the heart should survive the strain, which it does not do in the vast majority of cases, there is still the risk of hemorrhage and the possibility of sepsis and shock. The iliac arteries have been ligated for abdominal aneurism, following the principle of Brasdor and Wardrop, but this too has proved fatal. Various methods of compression have been advocated and even endo-aneurismorrhaphy has been tried, but unsuccessfully. The aluminum band of Halsted which would produce a partial but not a complete occlusion of the aorta seems to offer the most satisfactory method of treatment, if wiring and galvanism are not indicated. Various problems, particularly the strain upon the heart, render treatment of aneurism of the aorta a very unsatisfactory procedure. Experimentally, a portion of the abdominal aorta has been resected and a tube successfully sutured into the defect (page 73).

Aneurisms of the innominate seem to offer a field for the Moore-Corradi method, though they have been treated successfully by ligature. Apparently the best operation is distal ligation after Wardrop or Brasdor. Ligation of the right common carotid and the right subclavian is done during the same operation, tying the carotid first to avoid the possibility of a cerebral embolus.

Aneurisms of the external carotid are quite rare, but occasionally occur. Treatment by ligature, placing the ligature as far as possible from the bifurcation of the common carotid, may be employed. The injection into the external carotid of boiling water after the suggestion of Wyeth might be indicated, as the collateral circulation with the carotid of the other side is so free as to render simple proximal ligation much less likely to cure here than in most other arteries. Aneurisms of the com-

mon carotid or of the internal carotid are of grave significance because of the disastrous effect on the brain that often follows when these arteries are ligated. The danger of ligation of the common carotid increases enormously after forty years of age and is due to the diminished blood supply to the brain. In the young with elastic arteries ligation of the common carotid is comparatively free from danger, but after forty years of age, and particularly in the presence of arteriosclerosis, the occurrence of cerebral symptoms, from the inability of the other arteries to dilate sufficiently, is frequent. The operative measures that have been used are the classical methods of ligation, though of these extirpation with the double ligature has proved most successful. Proximal ligature is particularly liable to cause thrombi in the sac with the possibility of a piece of thrombus becoming loose and causing an embolus in the brain. This, of course, is in addition to the danger of cerebral symptoms from the mere occlusion of the artery. Distal ligation or extirpation to a large extent avoids the danger of embolus.

It has been found that cerebral symptoms may often be avoided if the channel of the artery can be reëstablished within a few hours after its occlusion. The problem in connection with the carotid artery is different from that in most other parts of the body, not only because of the immediate dangers to life, but because of the fact that we have a method of determining from the patient's sensations and symptoms whether occlusion of the artery is safe. Before applying a ligature to the carotid, except in cases of grave necessity, the common carotid should be exposed under local anesthetic and gradually occluded, preferably by a rubber covered Crile clamp. If this is followed by cerebral symptoms of a

psychic nature, by paralysis or convulsions, the artery should be opened at once. If no immediate symptoms occur, the clamp may be left on for forty-eight hours and then a ligature applied to occlude the artery with comparative safety. However, cerebral symptoms sometimes appear after several days, though they are usually manifest within twenty-four hours after occlusion of the artery. If complete closure is not possible the metal band of Halsted may be rolled around the artery in such a manner as partially to occlude it. If this is sufficient to cure the aneurism no further treatment is necessary; but if not the band may be left in place for one or two weeks until the other arteries have taken up the circulation, and then a ligature can be applied. If even a partial occlusion is not borne the outlook is almost hopeless, though the possibility of excision and the substitution of a segment of vein should be considered.

Subclavian aneurisms have been subjected to numerous methods of treatment, including the intrasaccular ligation of Syme. They have been treated by ligature, both distal and proximal, and the innominate artery has also been ligated in efforts to cure. The results have usually been unsuccessful, the mortality being large, though since 1890, the mortality has fallen from about eighty percent in preantiseptic days to twenty-two percent. The metal band may also be used here. Excision of the sac seems to have been followed by quite satisfactory results as compared to other methods of treatment. Endo-aneurismorrhaphy has been attempted, though in not a great number of cases, and the results have usually been most satisfactory.

Axillary aneurisms may be treated by ligature, by band, or by the operation of Matas. In certain cases where the circulation can be controlled, excision of the

aneurism with substitution of a piece of vein may be considered. This has been done by Lexer and while the patient died from gangrene of the limb it was found that the occlusion from thrombus occurred where the clamp was placed, the transplanted section of vein being patent and in good condition.

Treatment of aneurism of the iliac arteries is subject to somewhat the same objections as treatment of aneurism of the aorta, for ligation of these large arteries produces great strain upon the heart. The intrasaccular method of Matas offers in certain cases excellent results, though hemostasis may be difficult or impossible except by compression of the aorta.

The common and external iliac may be regarded as practically an extension of the aorta. Aneurisms affecting all of the iliac arteries are lined in front with peritoneum. They tend to dilate quickly as there is but little resistance in front and they rupture easily for the same reason. When rupture occurs it is usually immediately fatal, though occasionally the blood may form a large hematoma under the peritoneum. The treatment of aneurisms of the iliac arteries is confined to some form of ligature, to a partial constriction by the band of Halsted, or to endo-aneurismorrhaphy. Digital compression is not practical, though it may be tried by opening the abdomen and compressing the common iliac or the aorta. In extirpation or in endo-aneurismorrhaphy, temporary hemostasis can be effected by digital pressure on the abdominal aorta, or else upon the trunk of the common iliac near the bifurcation. Even pressure upon the aorta may not give an entirely dry field as some blood comes through the distal end by the deep epigastric artery. Pressure upon the iliac is often unsatisfactory because of the free anastomosis with the internal iliac of

the other side. Aneurisms of the external iliac have occasionally been treated by digital compression. Compression of the abdominal aorta through the abdominal wall is possible in thin patients, but is best done within the abdomen. In a thin patient the method of Momburg, constricting the abdomen with a rubber tube, may be tried. This will give a completely dry field, but there is always some danger from an abdominal tourniquet, such as injury to the intestines, though the originator of this method claims otherwise. The treatment of aneurism of the iliac has been largely by means of the ligature. Double ligation, distal and proximal, with extirpation has given satisfactory results. The iliac should be ligated intraperitoneally. The older method of stripping up the peritoneum and making an extensive raw surface is unnecessary. The patient may be put in the Trendelenburg position with the intestines packed off, and ligation of either the common iliac or its two branches can be readily done. Endo-aneurismorrhaphy has been tried in a few cases with satisfactory results. Ligation of the common iliac carries a heavy mortality rate. Matas says that in modern times, since 1880, the death rate is nearly fifty percent. This high mortality rate, as explained by Halsted in an article on aneurisms of the iliac, is largely due to complications and would probably now be considerably lower. The fact, however, that the mortality from simple ligation is much higher than from extirpation or endo-aneurismorrhaphy should cause the later method to be employed wherever possible.

Aneurisms of the upper femoral require a similar hemostasis to aneurisms of the iliac, as it is impractical to place a tourniquet at this level. The external iliac gives off but few branches whereas the upper part of the femoral has a very abundant collateral circulation. For

this reason in preantiseptic days ligation of the femoral just below the groin was avoided whenever possible. The collateral circulation was so free at this point that formation of a thrombus was prevented or retarded and as suppuration usually took place secondary hemorrhage would occur in about half of all cases; consequently, the external iliac whose branches are few could be ligated much more safely. However, now with the absorbable ligature and careful asepsis, these objections no longer hold.

In aneurisms of the upper femoral it is exceedingly difficult to obtain even temporary hemostasis unless the same measures are employed as in aneurisms of the iliac; that is, direct compression of the abdominal aorta or the common iliac after opening the abdomen. The communications of the profunda, which is almost always in the sac of an aneurism in this neighborhood, together with other collateral branches make the field very vascular. The necessity for controlling bleeding by intraabdominal pressure in such cases should be considered most seriously whenever it is desired to open the sac of an upper femoral aneurism.

Aneurism of the branches of the internal iliac practically always occurs either outside of the pelvis or else partly without and partly within the pelvis. It usually involves the sciatic or the gluteal arteries. Formerly, the most satisfactory treatment was the method of Antyllus where the vessel is ligated both proximally and distally and the sac incised. The better method is endoaneurismorrhaphy with either temporary or permanent closure of the internal iliac by ligature. When the aneurism begins in the pelvis, which is very unusual, merely ligating the internal iliac may be all that is necessary.

Aneurism of the lower femoral can be treated most

satisfactorily by endo-aneurismorrhaphy and here, as elsewhere, either the obliterative or, sometimes, the restorative operation is done. The reconstructive method, an attempt to build up a new channel out of the wall of the sac, should not be attempted. If after testing the collateral circulation it appears deficient and the patient's condition is otherwise good, the possibility of excising the aneurism and substituting a piece of the saphenous vein from the other leg should be considered.

Popliteal aneurisms may involve the whole of the artery in the later stages, but in the early stages they are often of the saccular form in which a very small portion of the artery is affected. In several instances the aneurism has been excised and the ends of the artery united by end-to-end suture. Aneurisms arising from the upper part of the popliteal are much less likely to cause gangrene than those from the lower portion of this artery, because most of the collateral circulation from the articular, azygos, and muscular branches opens into the lower portion of the popliteal. The former treatment of popliteal aneurism was peculiarly unsuccessful. Various methods of ligation have been used. As popliteal aneurisms comprise about one-third of all aneurisms, excepting those of the aorta, the clinical material for operative treatment has been very largely drawn from those of the popliteal type. Of the various methods of ligation the Hunterian has been the most popular, but the radical operation consisting either of extirpation of the sac or the operation of Antyllus, a distal and a proximal ligature and incision of the sac, has given better results. Endo-aneurismorrhaphy is peculiarly applicable to popliteal aneurisms and in sixty-two cases there was only one death which was due to tetanus and two cases of gangrene, and in both of these instances the vein

that accompanied the artery was injured and had to be ligated. This, of course, was not a fault of the method. In all others recovery occurred. There were secondary hemorrhage and relapse in four cases, but in these the reconstructive method was used, proving the wisdom of adopting the obliterative type of endo-aneurismorrhaphy. In one of the author's cases in which the obliterative operation was done for a popliteal aneurism, the result was entirely successful.

CHAPTER XIII.

ARTERIOVENOUS ANEURISMS.

Arteriovenous aneurisms are lesions in which there is a communication between an artery and a vein. The vein may be a sinus in the dura mater. They are usually subdivided into two forms, varicose aneurism, in which the communication between the artery and vein is indirect and a sac exists between the two vessels; and aneurismal varix, in which the blood flows directly through the opening from the artery into the vein. There are many combinations such as a sac in the artery opposite the opening into the vein or there may be two sacs, one on the artery opposite the opening and one between the artery and the vein. The vein becomes dilated, particularly the proximal vein, unless the parts around it form a firm support. Dilatation of the vein is called varicose aneurism by dilatation.

Secondary arteriovenous aneurisms are found in the region of the heart and around the aorta where a preexisting aneurism has ruptured into a vein. The most frequent cause of arteriovenous aneurism is trauma, a gunshot wound being the common form of traumatism. The modern bullet which makes a small puncture is very likely to cause an injury of this nature. Formerly, when bleeding was in vogue, arteriovenous aneurism at the elbow with a communication between the brachial or the ulnar artery and a vein, was comparatively frequent. Fractures, stabs, or indirect injuries may also result in arteriovenous aneurism, but occasionally it oc-

curs spontaneously, which is rare and is probably due to some degeneration in the wall of the artery that permits perforation at this point. The distal portion of the artery becomes contracted and narrow, since it is subject to less than its normal pressure as a portion of the blood intended for it is delivered to the vein. The central segment of the artery, however, is much dilated. This was supposed at one time to be due to a kind of atrophy and thinning of its walls, but is now believed to be a genuine hypertrophy of the vessel itself in an effort to bring enough blood to the seat of the lesion to supply the distal parts satisfactorily even in the presence of the leak into the vein. The vein is also dilated distally up to the first valve and centrally for a much longer distance. Sometimes the valves are forced by the pressure of the blood stream or by damming back of the blood and a large varicose tumor may result. The dilatation of the vein is very much influenced by the surrounding tissue. The vein gradually thickens and becomes more and more like an artery.

Owing to the marked activity of the circulation in arteriovenous aneurisms and the great difference in pressure between the venous and the arterial trunks, clots rarely form and the prospect of spontaneous cure is very slight indeed. The liability to rupture depends to a large extent upon the size and location of the sac. An aneurismal varix rarely ruptures. Sometimes the crowding of the arterial blood into the vein causes swelling from damming back of the venous blood, and at the same time nutritional disturbances may appear because too little blood enters the artery distal to the lesion. All of these things, however, depend entirely upon the location of the arteriovenous aneurism and the size of the opening. A very small leak will interfere but little,

whereas a larger one may switch back so much of the blood that nutrition is greatly impaired.

In large arteries an opening of considerable size may cause so much pressure in the venous system as to produce dilatation or hypertrophy of the heart. In a case that the author operated upon (page 252) there was a large opening between the upper femoral artery and vein, and all four valves of the heart were incompetent. The lesion may appear immediately after the infliction of the injury or more frequently after an interval of time. Some cases are reported in which the symptoms occur months or years after the injury, but this is unusual and is probably due to yielding of the scar. Usually the clots and the pressure from the surrounding exudate will prevent a free communication for several days.

The thrill is marked in all arteriovenous communications. It can be felt distinctly at the site of the lesion and along the course of the vein both distally and centrally. The bruit can be heard and is much more distinct than in simple aneurisms of arteries. Often the vibrations along the course of the vein can be seen. The thrill is continuous but is most intense with each systole of the heart and at the exact site of the anastomosis. The noise has been compared to the buzzing of machinery, or to the sound made by a bee in a paper bag. This sound varies in character and in pitch but is present in some degree at all times. It ceases completely when the artery is compressed on the cardiac side of the lesion. It is caused by the vibration produced from the rapid whirl of the blood current in going suddenly from a vessel of high pressure to a cavity of low pressure, just as a noise is made by the passing of water from a high pressure pipe to one of low pressure. Neither the edges of the opening nor the vessels have anything to do with

the sound, which is produced solely by the blood current.

The pulse in the artery is stronger above the lesion and weaker below the lesion than it would be normally. It is also somewhat delayed below the lesion. Pulsation in the vein is sometimes felt, though this depends upon the size of the opening and also upon the size of the artery. Pressure upon the artery centrally to the lesion not only stops the sound but also causes a marked diminution in the size of the tumor. Superficial veins in the neighborhood are usually enlarged. The temperature of the limb distal to the aneurism is lowered, at least until a satisfactory collateral circulation has formed.

If a large communication exists between the aorta or the iliac arteries and the adjoining vein, the prognosis is most unfavorable. The decrease in blood pressure because of the large leak from the arterial system into the venous system, which has a much larger capacity, might so lower the blood pressure as to cause death.

The prognosis of arteriovenous aneurisms depends upon three things: first, the location, whether in a large or a small vessel; second, the size of the opening; and third, the presence or absence of a sac. A large opening in large vessels, even if the blood pressure could be maintained, is likely to put too great a strain upon the heart. On the other hand, an arteriovenous aneurism in a small artery is of but little significance and would interfere very slightly with function or with the general health. There is but slight chance of rupture, when compared with aneurisms of the arteries, and this infrequency of rupture with the difficulty of cure has led the older surgeons to avoid interference in arteriovenous aneurisms.

Treatment.

It has been the experience of most surgeons who have had considerable clinical material that unless there is grave danger it is best not to operate upon these injuries too soon. The patient should be given the benefit of rest and kept as quiet as possible to reduce blood pressure. This treatment is continued for two or three months after the injury unless there is a marked tendency for the lesion to become worse. At this time whatever sac may have occurred will be firmly organized and the collateral circulation will be amply established. Recent experience in the Balkan wars, however, seems to indicate that immediate operation is best.

Immediately after the injury, pressure over the lesion and on the main artery by a firm dressing and bandage and absolute rest are indicated. The various methods of ligation have not proved very satisfactory. Proximal ligation is often followed by recurrence and distal ligation alone is, of course, never indicated. The quadruple ligation, tying artery and vein both above and below, with or without extirpation of the sac, has cured most cases, but is often followed by gangrene owing to the fact that both the artery and vein are sacrificed at the same time.

The ideal method of treatment is restoration of the lumen of both the artery and vein. Where a sac exists, the method of Matas, the restorative endo-aneurismorrhaphy, may be practiced in some cases. The fact, however, that the sac is practically always a false sac and is not continuous with any of the coats of either artery or vein would make the application of this method a little less certain than in a restorative endo-aneurismorrhaphy on a spontaneous aneurism. If a sac ex-

ists it is opened, and the aperture in the artery sutured with interrupted catgut stitches. When the artery and vein are both closed in this manner the sac is partly obliterated by catgut stitches which tuck a portion of the sac over each opening. In an aneurismal varix the vein may be incised and the opening into the artery is closed within the vein, then the vein itself is sutured. This latter procedure probably causes a thrombus in the vein even if the suturing in the artery held. If it is possible to secure complete hemostasis the most satisfactory way is to dissect free both the artery and vein and to suture the wound in each vessel, following the technique of arterial suturing. This, of course, would necessitate the edges of the wound in the artery and vein being carefully cut away with sharp scissors, the adventitia removed, and the wound approximated according to the technique described under the head of suturing lateral or transverse wounds in blood-vessels. As much tissue as possible should be preserved so that a double mattress stitch may be used, approximating accurately the intima and at the same time not sacrificing the lumen. The dilatation of the vessels toward the heart, together with the contraction below the lesion, places considerably more strain upon the sutures than would be the case after an ordinary wound of the vessel. This strain should be relieved by the application of a strip of fascia, a large absorbable ligature, the Halsted aluminum band or infolding the artery according to Matas and Allen, in order partly to occlude the vessel proximal to the lesion. Or a ligature may be thrown around the artery with instructions to tie it quickly if secondary hemorrhage occurs. If there is no infection the danger from secondary hemorrhage should be over in a week or ten days.

When it is impossible or impracticable to secure complete hemostasis by a tourniquet the problem is much more difficult. If the nutrition of the limb is seriously affected, or if the heart shows signs of failing under the extra strain on the venous side, operation should be attempted. In a heart that is already incompetent, pressure upon the aorta or ligation of a large vessel might result disastrously and the safer method under such

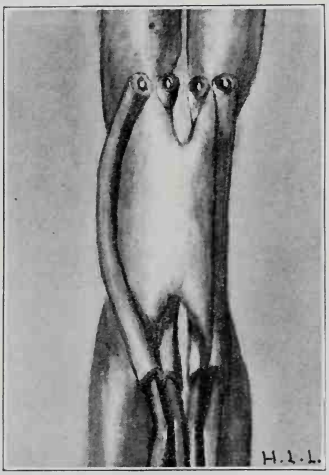

Fig. 73.—This shows how the clamps for lateral suture may be applied on an arteriovenous aneurism without the necessity of fully dissecting out the aneurism.

circumstances would be to reëstablish the circulation in both the artery and vein. Here it is advisable to dissect both vessels carefully, exposing the lesion and then to grasp the artery and the vein with curved forceps for lateral suture of blood-vessels (page 85). After grasping the artery and vein their communication is severed, the edges of the wound in the vessels properly trimmed, and with a cobbler's stitch in straight arterial needles or an overhand stitch in a curved needle, the opening in the artery and then in the vein is closed (Figs. 73 and

74). If possible without too much constriction of the lumen, a continuous reënforcing stitch over this may also be used. The lumen of the artery should be partially occluded on the cardiac side, as already mentioned.

A case of arteriovenous aneurism between the femoral artery and vein about two inches below Poupart's ligament on which the author operated at a clinic in the Medico-Chirurgical College, through the courtesy of Prof. W. L. Rodman, may be of interest in this connec-

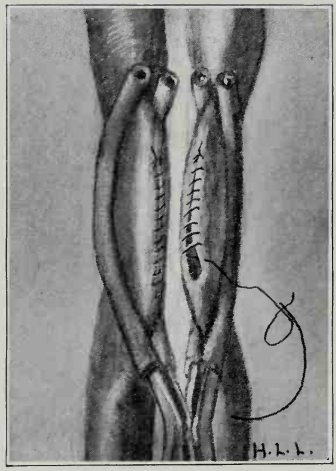

Fig. 74.—The communication between the artery and vein has been divided and the vessels are being sutured. It is best to use a cobbler's stitch and fine arterial needles in the artery, but if this is impossible, a fine curved needle may be used.

tion. Four years ago, the patient, a pullman car porter, had fallen on a sharp stick and injured his left thigh about two inches below Poupart's ligament. Several months after the wound had healed, he noticed a swelling in this location. It would sometimes be quite large. Gradually the pain became greater and greater and it was difficult for him to work. On admission to the Medico-Chirurgical Hospital, all valves of the heart were found incompetent and the thrill and bruit in the

region of the scar were intense. The pressure in the venous system was evidently so great as to affect his heart most seriously and the indication was to relieve his heart by an attempt to cure the arteriovenous aneurism. The location was too high for a tourniquet and the condition of the patient's heart rendered it unwise to compress the aorta. After carefully dissecting free the vessels involved, the femoral artery just above the lesion was found greatly enlarged and the femoral vein much dilated. In an effort to free the artery posteriorly, considerable bleeding was encountered. The profunda artery was clamped and the vessels going internally cut and tied, as they hindered the dissection. Adhesions from the scar tissue posteriorly and numerous vessels here that tore easily rendered the dissection behind the femoral impossible. Though a Crile clamp was placed on the artery above and below the lesion and also similarly on the vein, and though the profunda was clamped, the communication between the femoral artery and vein when incised bled freely. The tip of the index finger was at once inserted and in this manner the bleeding was checked. The vein was clamped by a soft Doyen intestinal clamp. Pressure over the artery in certain directions controlled the collateral branches that evidently came in from behind. No attempt was made to follow the regular technique of arterial suturing as the vessels would bleed profusely after pressure was removed and it was impossible to do the suturing in a perfectly dry field. The thread, however, was anointed with vaseline and the wound in the artery was closed by a continuous stitch of moderately fine silk in a curved needle. The wound in the vein was easily sutured. The distal clamp was removed and the proximal clamp was gradually loosened. The exceedingly large size of the femoral artery above and the

impossibility of carrying out the regular technique of arterial suturing made it doubtful whether the sutures in the artery would hold. At the same time it was recognized that ligation of the dilated femoral would throw so much extra strain upon a heart whose valves were already incompetent that a cardiac death might result. Consequently, ligatures were placed around the artery and vein, both above and below the lesion, with the idea of tying these ligatures if serious hemorrhage occurred later. The wound was perfectly dry when closed. There was a small drainage provided at both the upper and lower angles. The night following the operation considerable hemorrhage occurred and the ligatures were tied and an additional ligature placed on the artery. The next morning the patient's pulse was good and the leg was warm and seemed to be well supplied with blood. He did well for fifteen days when he had a severe secondary hemorrhage, for which Dr. Rodman ligated the external iliac. This completely controlled the hemorrhage and the patient was apparently improving until the twenty-first day after the operation, when symptoms of acute cardiac dilatation occurred and he died within twenty-four hours. There had been no further hemorrhage, however, and a post-mortem examination showed there was no bleeding, but that death was due to dilatation of the heart. Such cases are always desperate but if they can be treated before the heart becomes so markedly diseased the prognosis would be better.

CHAPTER XIV.

TUMORS OF THE BLOOD-VESSELS.

A true tumor of the blood-vessels springs from a matrix of cells that is formed either in the embryo or in later life. It is not a part of the normal anatomical structure. Tumors of blood-vessels may consist chiefly of arteries, chiefly of veins, or chiefly of capillaries, but all have to some extent other types of blood-vessels. They are named, however, after the predominant type. The kind very commonly found is composed of dilated capillaries that lie within the skin. They produce the color often referred to as "port-wine mark," due to the large number of new dilated capillaries. If chiefly from the arterioles, the color is decidedly red; if the dilatation is largely on the venous side it is dark purple. The skin is usually not elevated above the normal and the appearance is suggestive of a deep and irregular stain. Some authors have claimed that these capillary angiomas follow the distribution of the branches of the fifth nerve, though these findings are not generally borne out by other observers.

Cushing suggested that these angiomas are often found in the dura when present on the face and not infrequently cause hemorrhage, which may be serious. Such a possibility should be borne in mind in all cases in which sudden cerebral symptoms arise in a patient who has a capillary angioma on the face.

The histologic appearance shows a large number of well formed capillaries and small blood-vessels, and fre-

quently many lymph vessels. The growth is painless, though the disfigurement is so marked that it may be the cause of nervous symptoms in a person of sensitive nature.

Treatment depends to some extent upon the location and extent of the growth. If small and conspicuous it can usually be excised and the skin around the edges undermined so as to bring the margins of the wound together in a straight line. The skin should be sewed subcutaneously to leave but little scar. A subcuticular stitch of tanned catgut makes a very satisfactory union. This may be reënforced by the epithelial stitch of Halsted, fine silk in a fine round needle, merely taking the edges of the epidermis. If, however, the angioma is extensive as is often the case, other measures are preferable.

The many kinds of treatment formerly employed, such as the application of nitro-muriatic acid, cauterization with the actual cautery, or the injection of astringent solutions, have now been practically abandoned. If the nevus is too extensive for excision it should be treated either by electricity, carbon dioxide snow, or liquid air. The older method of electrical treatment consisted in inserting a needle into the growth at various spots and connecting it with the negative pole of a galvanic battery. A current of about twenty milliamperes was turned on for about ten minutes and increased shortly before withdrawing the needle. This has to be repeated often and frequently leaves considerable scar. The modern electrical treatment by desiccation is far better. The bare electrode does not come in contact with the tissues, but the current from one pole is thrown from a metal part through a small air space in the form of sparks of high frequency. The other pole is grounded. If deeper ef-

fect is desired the bipolar method is used. Here the metal point touches the tissues and a large passive electrode is placed on some other portion of the body. A static machine with an output of from two and a half to three and a half milliamperes produces a satisfactory initial current which is gradually increased. Desiccation seems to dry the tissues and sterilize them. It causes a rapid dehydration and ruptures the cell capsule. It has the power of penetrating the tissues for as much as an inch, though usually it penetrates efficiently only for a much shorter distance. A small growth may possibly be destroyed at one sitting but a large growth requires several treatments. The desiccated tissue causes a reaction and hyperemia which usually produces rapid repair. The crust that forms separates in a few days or a week. Often regeneration will occur without scar. The application is not very painful, but if the individual is sensitive a local anesthetic may be employed. This treatment should not be used, however, when there is any reasonable suspicion of malignancy.

Another method of treating extensive nevi or birthmarks is refrigeration. It gives most satisfactory results. Carbon dioxide, which is employed for freezing, is readily procurable in iron drums from soda water manufacturers or from saloons where beer is sold. To collect the frozen gas or "snow," as it is called, the iron drum is tilted till the outlet is at a low point. This insures the exit of the liquid. A piece of chamois skin is then tied around the outlet and collects the frozen gas. Special attachments are also on the market for collecting the gas. If chamois skin is employed the "snow" can be rolled in the chamois skin or packed in hard rubber molds to form a stick or pencil. Any grade of refrigeration may be obtained, depending upon the dura-

tion of the application and the amount of pressure. For small lesions, about the size of a nickel or smaller, one application usually suffices. For larger growths, several are necessary. For the ordinary flat nevus an application of from ten to thirty seconds is enough. When used on large nevi that are somewhat deeper and with a thick skin, an application of a minute or more may be necessary. Some authorities claim that exposure to X-ray renders the tissue more susceptible to freezing. The treatment is followed by a disagreeable burning sensation and usually by blistering. Ordinary dusting powder of borated talcum is used as a simple after-treatment. The principle of both refrigeration and desiccation is that the endothelial cells of the blood-vessels are destroyed and consequently the vessels disappear.

In capillary nevi, "port-wine marks," the small capillaries are dilated either in a spindle-shape or in a saccular form. In the cavernous or venous angioma, the vessels are larger and more deeply situated and desiccation or freezing is inapplicable, as these remedies cannot penetrate deeply enough to destroy all of the elements of the anigoma without causing an extensive slough. A cavernous angioma is raised above the surface and sometimes attains very large proportions. It is soft and easily compressible, the blood, however, filling up the growth quickly whenever pressure is removed. A venous angioma may arise as a growth of new veins or it occasionally occurs as a sequence of a capillary angioma that tends to grow deeper into the tissue, its vessels communicating and forming large lakes of blood. The walls of a cavernous angioma are very thin and they may be easily injured. A wound of such a growth is followed by profuse and sometimes fatal bleeding. Cavernous angiomas are seen on the face frequently, as

is the capillary angioma or nevus, and are also found in the liver, muscles, and sometimes in the kidney and other organs. The nose or the margins of the eye are favorite portions of the face for this growth. It is said that it is likely to occur where the fissures of the face are obliterated.

The treatment for capillary angioma or nevus is hardly applicable to cavernous or venous angiomas, except so far as they may be excised. Radium, however, can be used for any kind of angioma. It seems to have a special tendency to cause obliteration of blood-vessels. Care should be taken in excision not to cut through the tumor tissue itself, as almost uncontrollable hemorrhage may be encountered. If such a growth has been accidentally injured it is useless to attempt to catch the individual vessels but sterile gauze should be packed in the wound and firm compression made. This packing should not be removed for several days. In excision the cut is made in healthy tissues where normal vessels are encountered and the blood supply dealt with in the usual manner. In large angiomas, however, this would be impracticable and often the excision of so much tissue leaves a very bad deformity. Most angiomas have a congenital origin and sometimes grow rapidly, and the effects of their pressure upon the surrounding tissue, even upon the bone itself, may cause atrophy and leave marked deformity. Another objection to excision in any but the smallest tumors is the fact that frequently matrices of the blood-vessels, angioblasts, may exist around the margin of the growth in what appears to be healthy tissue; small blood-vessels from the growth also jut out irregularly. In order to include these, a wide margin of healthy tissue would have to be removed, else some of the abnormal vessels left may renew the growth.

The treatment devised by John A. Wyeth, of New York, is most satisfactory for cavernous angiomas that cannot readily be excised. This consists of the injection of boiling water into the growth. The water mixes with the blood and the heat destroys the endothelial lining of the blood-vessels. In a large growth a series of injections are required. The injections are made with an all metal syringe capable of holding about two ounces of water. A moderately coarse aspirating needle is used. The syringe is filled with boiling water and the barrel of the syringe heated over an alcohol flame or a Bunsen burner. The patient is anesthetized and the eyes and the skin surrounding the growth as well as the growth itself are anointed with sterile vaseline. The rest of the face is covered with moist gauze to prevent scalding, as a few drops of water may escape from the syringe. The syringe is held with dry gauze or a dry towel. If the gauze or towel is wet it cools the syringe too much. The needle should not be too fine as it would make the stream of water so small as to reduce its temperature unduly. After plunging the needle into a prominent portion of the growth, blood flows for a few seconds, but is readily controlled by the hot water. The water is injected rapidly until the tissues become tense. The needle is then shoved to another portion of the growth and a further injection given. Even in a large growth an effort should be made to cover the most prominent parts at the first sitting. If the injection is made too slowly the heat is so reduced as to prevent its injurious effect upon the vascular endothelium. Considerable swelling follows for several days and gradually subsides. No other injections should be made for ten days or two weeks. If at the end of that time soft areas show where blood-vessels have not been destroyed, an-

Fig. 75.

Fig. 76.

Fig. 75.—Photograph of a boy, J. P., thirteen months old with a large angioma of the nose which was growing rapidly.
Fig. 76.—Another view of the angioma of boy shown in Fig. 75.

Fig. 77.—A photograph of J. P. about eighteen months later after a series of injections of hot water by the method of Wyeth.

other treatment can be given. The patient should then wait for at least a month before further injections, as the injurious effect of the anesthetic, together with the absorption of the products of the injured cells are too irritating to permit treatments in rapid succession.

The author has used this method successfully in several angiomas of the face and in a large angioma of the umbilical region. The accompanying photographs of a little boy show the results of injection of hot water in a large cavernous angioma of the nose. About fifteen injections were made extending over a period of eighteen months (Figs. 75, 76 and 77).

There is but little danger from emboli if the injection is made quickly, for the large blood cavities will rapidly form clots that are too big to enter a small vessel. The usual antiseptic precautions should be taken, but the sterilizing effect of hot water is sufficient to insure against septic clots. Sometimes if the skin is very thin it may slough. The heat often produces a blister. The skin is dusted with boric acid or some antiseptic ointment is applied immediately after the injection. This treatment is hardly suitable for capillary angiomas, as these vessels are so superficial that the heat necessary to destroy them may also destroy the skin. It is well suited for a cavernous or venous angioma, as the hot water will follow the various sinuses and vessels and destroy vessels that could not be excised except by taking out a great deal of healthy tissue.

The old method of running threads through an angioma or leaving other foreign bodies in its substance has been generally abandoned. Not only is it usually inefficient but small clots may form which cause emboli and the danger of sepsis is great.

Arterial angioma, or cirsoid aneurism, which goes un-

der many names, is usually found about the face or hands. It consists largely of masses of arteries that are very tortuous and communicate with each other. Their pulsation sometimes causes erosion of the bone. Rupture of these vessels often results in an alarming or even fatal hemorrhage. Arterial angiomas frequently arise from small nevi and occasionally follow an injury. The large vessels may become confluent and form a cavity. A thrill and bruit may exist over the region of these angiomas.

The treatment of such a condition has not been satisfactory. Subcutaneous ligation has been tried but is not often followed by cure. The best treatment is ligation of the main artery that supplies the aneurism, as, for instance, in cirsoid aneurism of the forehead ligation of the external carotid. Often communications with other arteries are so large and numerous that this is not effective. Following the method of Wyeth, the artery that directly opens into the cirsoid aneurism can sometimes be dissected free, the central end ligated, and hot water quickly injected into the distal end. Pressure should be maintained around the margins of the growth to prevent a too quick return of the hot water into the veins. The injection of astringents would hardly be wise.

CHAPTER XV.

VARICES; VARICOSE VEINS, VARICOCELE, AND HEMORRHOIDS.

Varicose veins are merely dilatations of previously existing veins and so, of course, differ from true tumors considered in the previous chapter, which consists of new growths composed of abnormal vessels. Varicose veins of the leg are more common in the left leg for the same reasons that phlebitis is more frequent in the left leg than in the right. The manner of the left iliac veins crossing under the iliac arteries, the slightly longer course of the left iliac vein, the pressure of the distended sigmoid, are all given as factors that make varicose veins in the left leg more frequent than in the right leg. The pressure of a tumor or growth in the pelvis or in the iliac fossa may also be a cause as well as some defect in the valves that permits blood from the femoral vein to run backward into the saphenous.

Varicose veins are more prominent when the patient is standing and vary from a slight dilatation to large, bluish masses that disappear on pressure. They are always tortuous and in advanced cases extend from the ankle to the saphenous opening. The veins sometimes vary in size, becoming larger or smaller at different times. It is quite common to find varicose veins much worse during pregnancy. This is not due solely to the pressure of the uterus, because the veins often begin to enlarge in the first month of pregnancy before pressure begins. The dilatation may be fusiform or sacculated

and only certain portions of the saphenous vein may be affected. The sluggish circulation promotes clotting which causes a still further damming back of the blood and so increases the dilatation of the vein. The dangers of embolism from varicose veins are obvious. Sometimes the vein is so large and thin that it ruptures and serious hemorrhage may occur. In the advanced stage all the valves of the saphenous become inefficient, and the long column of blood has no support except at its base.

Trendelenburg tested the efficiency of the valves by elevating the leg for a short time, stroking the blood toward the heart and then compressing the saphenous trunk. With the saphenous still compressed the patient stands up and the dilated veins below gradually fill with blood from the foot and leg. When the compression is removed the blood suddenly rushes into the saphenous from the femoral vein. If, however, the valves are efficient this latter phenomenon does not occur.

Various disturbances arise due to the obstruction of the venous circulation. The skin of the leg and foot becomes bluish-red, infiltrated, and liable to inflammatory affections, particularly to eczema. The slightest injury heals over with difficulty and ulcers readily form. The ankle, foot, and sometimes the leg swell after standing for some time. In chronic cases, new connective tissue forms and produces a permanent thickening. The fat over the veins disappears and the veins become adherent to the skin. If a vein ruptures and a thrombus occurs the skin in the immediate neighborhood often breaks down readily. The patient has muscular weakness, and complains of indefinite pains and aching in the leg and foot. Sciatica may occur. Some patients suffer a great deal, while others apparently have but little dis-

comfort. The rupture of small veins beneath the skin is often followed by brownish pigmentation of the skin. This is very common about the ankle. Inflammation of the veins is readily accompanied by thrombosis. Bone in the vicinity of the ulcers sometimes becomes necrotic.

Varicose veins are very insidious in their growth and frequently accompany diseases that either directly affect the circulation, such as heart disease, or weaken the general resistance of the patient. It is undoubtedly true that many families have a tendency to varicose veins. Varicose veins usually begin in the small, superficial veins about the middle of the leg, though they may originate from the veins about the ankle or even in the neighborhood of the knee joint. They are bluish or purplish in color and radiate from one spot. Occasionally, the large trunks of the leg or thigh are first involved. Some authors claim that varicose veins originate in the deep veins and extend to the superficial, though this is not borne out by most observers. When varicose veins are limited in character they are usually found where the large perforating branches enter the superficial veins from the deep veins.

There are three forms of veins in the lower extremity; (1) those without valves in which the blood may run either way, (2) veins in which the valves direct blood toward the surface, and (3) those in which the valves direct the blood toward the deep veins. The perforating branches are most numerous in the middle and lower part of the leg. In the middle of the leg they are surrounded by muscle and these are frequently the first to dilate. Often the process extends from this point to the other veins. The veins are elongated and become very tortuous and the walls in the later stages are thick from connective tissue. Standing is much more likely to produce

varicose veins than walking, for the tension on the muscles compresses the deep veins constantly in standing, whereas in walking or in running there is alternate tension and relaxation which serves to empty the vein.

The complications that often occur are pigmentation of the skin, eczema, ulceration, and neuralgic pain. Some of these complications are supposed to be trophic. Occasionally the pain may be very severe and may even involve the sciatic nerve. Ulcers are difficult to heal permanently unless the varicose vein, which is the cause of the ulcer, is excised. Club-foot has been mentioned as one of the sequelæ of varicose veins due to muscular changes and to the trophic and nervous disturbances. This, however, must be exceedingly rare.

The treatment of varicose veins may be operative or nonoperative. Nonoperative treatment should be used in mild cases. The indications here are to improve the general health and regulate the nutrition and personal hygiene. Particularly should constipation be overcome. If an employment requires constant standing the occupation should be changed or the patient required to sit, elevating the legs whenever possible. In the absence of phlebitis massage toward the heart is of some value. Any constriction, such as circular garters or tight bands around the waist, should be prohibited. If the varicose vein is localized and without disagreeable symptoms no other treatment is necessary. If, however, it tends to extend, some form of compression should be used. Stockings made of rubber and silk are probably the best. The toes and the heel should be left exposed, and the stockings should not go above the knee. Flannel bandages or bandages made of some washable webbing that can be cleaned and reapplied when necessary are cheaper and often just as effective as the most expensive elastic

stockings. Any treatment depends, of course, upon the cause of the varicose veins. If due to heart disease elastic stockings or bandages that increase blood pressure are contraindicated.

The operative treatment consists of ligatures or excision of the veins. These two operations are of very ancient origin, though they have been modified from time to time. The injection of astringent material into the veins has also been advocated, though it is not practiced to any extent at the present day and is undoubtedly liable to cause thrombosis and embolism. The ligation may be merely tying the main trunk or using many ligatures in such operations as advocated by Schede or Friedel. Schede completely encircles the leg with an incision about the junction of the upper and middle thirds, cutting all veins and tissues down to the fascia of the muscle. The veins are then tied and the skin sutured. Friedel makes a spiral incision starting below the knee and encircling the leg five times, ending on the back of the foot. All veins are tied but the wound is left open to drain away the lymph. Multiple ligation of the main trunk with its branches has been advised, some surgeons using as many as thirty or forty ligatures.

Resection of the saphenous vein may be partial as recommended by Trendelenburg, who ligates and resects the saphenous vein in three places, at the middle of the thigh, and above and below the internal condyle. Total resection can be done by a long incision made from the saphenous opening to the posterior border of the internal condyle and then continued to the internal malleolus. If an ulcer is present the incision does not reach as far as the ulcer so as to avoid infection. A better method of excision is that recommended by C. H. Mayo and consists of multiple short incisions over the course of the

saphenous vein (Fig. 78). The vein is ligated and stripped subcutaneously. This may be done by threading it through a special instrument such as has been devised by Mayo. The upper incision is made just below the saphenous opening. The vein is doubly tied and divided between ligatures. The lower end is threaded through a special instrument that resembles somewhat a

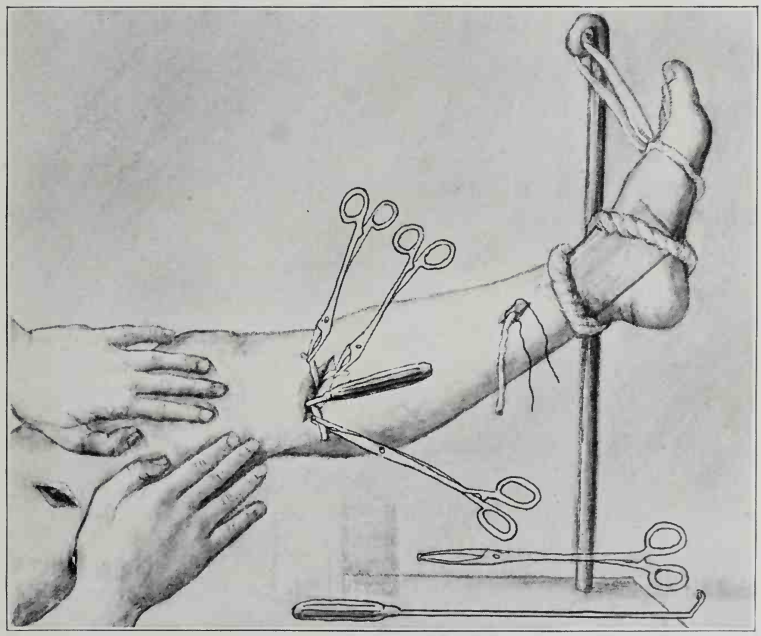

Fig. 78.—Method of Charles H. Mayo of stripping out varicose veins through multiple short incisions. Two special instruments for stripping veins are shown at the bottom of the illustration.

blunt curet. The instrument is shoved down on the vein, so stripping it from the surrounding tissues and tearing many small branches. When the vein is stripped as far as possible in this manner an incision is made over the elevated beak of the instrument. The vein is brought up at this point and the instrument withdrawn from the first incision and inserted into the second incision. The

vein is again stripped. No incision should be made on the level of the knee as the scar may interfere with the motion of the joint later on. If the varicose veins are extensive, it is impossible to strip them much below the knee as the branches in this region are large and quite numerous. Here an incision may be made either curved or straight, so as to expose the greatest number of veins, which are then excised. The methods of stripping the veins from below upward are dangerous because of the possibility of thrombus and embolism. Babcock and others have devised an instrument somewhat like a long probe with a bulbous end, resembling a bougie with a long handle. The handle is inserted into the vein, the bulbous end being too large to enter. The handle is cut down upon and the vein in this way turned wrong side out.

The operation suggested by Delbet of anastomosing the internal saphenous to the femoral vein at a lower junction than normal is hardly justifiable.

Varicocele.

Variococele is the name applied to dilated veins in the spermatic cord. It is common in boys about fifteen or sixteen years of age and in young men. Unfortunately quacks and advertisers have so exaggerated the significance of this trouble, that many young men have an erroneous idea of its importance. It is normal for the veins to enlarge somewhat at certain times of life. If, however, the enlargement is excessive the condition becomes one that should be treated. The local signs and symptoms are quite characteristic. Varicocele is more frequent on the left side than on the right. This is probably due to the fact that the left spermatic vein empties at practically a right angle into the left renal vein,

whereas the right spermatic vein has a shorter course and empties obliquely into the vena cava. Constipation with a chronically filled sigmoid may also be a causative agent here as well as in varicose veins of the leg. If the condition becomes aggravated, the veins are exceedingly prominent and the scrotum is much elongated, particularly in warm weather. The veins resemble the old description of "feeling like a bunch of earth worms." Often there is an impulse on coughing, which is not easily confused with the impulse from hernia on account of the peculiar consistency and distribution of the varicocele. When the patient lies down the veins are emptied and the swelling to a large extent disappears, though in old cases where the walls of the veins have thickened they can be felt even when the patient is reclining. If the condition is aggravated and prolonged, sometimes atrophy of the testicle occurs as a secondary change from passive hyperemia. Dull aches and a dragging sensation are frequently complained of. There are often various nervous symptoms that may merely accompany, and not be caused by, varicocele.

One of the most important things about varicocele is its diagnostic significance of a tumor of the left kidney. As the left spermatic vein empties into the left renal vein, a tumor of the left kidney that compresses the renal vein is likely to cause a left varicocele. Varicocele is a disease of youth. No particular importance can usually be attached to its development in the young. However, in the middle aged or old the rather sudden occurrence of marked varicocele on the left side should always attract the attention of the surgeon to the possibility of a tumor of the left kidney.

The treatment of varicocele in boys or young men often requires merely moral reassurance that the condi-

tion is not a serious one. Cold baths each day, regulation of the bowels, and personal hygiene should be recommended. If the varicocele is marked, a snugly fitting suspensory should be advised. If the condition has existed many years and the scrotum is much relaxed, and particularly if accompanied by dragging or neuralgic pain, operation should be performed.

The operation consists either in ligation or excision of the veins. Formerly, subcutaneous ligation was much practiced, but this operation has justly fallen into disrepute. Ligation should be done through an open incision, which may be high in the upper part of the scrotum and lower portion of the inguinal canal, or low down about the center of the scrotum. When the scrotum is not shortened the high operation offers many advantages. The incision is about two inches long, its upper end corresponding to the external inguinal ring. The structures of the cord are freed and drawn into the wound. The vas is recognized by its denseness, feeling like a wire or whip-cord. The vas should be separated with a few veins and the spermatic artery from the rest of the cord and held aside by a piece of gauze. Care should be taken not to bruise the vas by strong traction or by catching it with forceps. The rest of the veins and tissues of the cord are then ligated close to the upper angle of the incision, using catgut. The ligatures are tied very tightly, preferably holding the first turn of the knot with forceps while the second turn is run down. Two ligatures are applied about one-fourth of an inch from each side. The ends of the lower ligature are left long. A sufficient amount of the veins is pulled up to draw the testicle well up from the bottom of the scrotum. Two ligatures are applied at the lower end in the same manner as the upper end. The intervening segment of

veins is excised and the two venous stumps tied together by the long ends of the ligatures. Each bleeding spot is tied and the wound closed without drainage. A suspensory bandage should be worn for some months after the operation. A hard mass around the ligatures may exist for a month or more.

As a rule, when an operation for varicocele is indicated, the scrotum should be resected. A relaxed scrotum that does not afford support to the testicle but permits the testicle to dangle from shortened cords will not give an ideal result. Most varicoceles are accompanied by relaxed scrotums, so the operation should be devised to accomplish both the resection of the veins and shortening the scrotum. If a transverse incision is made, its two ends form projecting points or teats, which frequently become irritated, and the scar is always wide. A better plan is to resect the scrotum along the middle line, parallel with the median raphe. As much of the scrotal tissue as should be removed is taken up and clamped with one or two pairs of curved pedicle forceps. This redundant scrotum is then cut away with a sharp knife or scissors on the *proximal* side of the clamp, so as to leave no bruised tissue for healing. This should be done quickly and the bleeding points all carefully clamped, otherwise they retract and leave a hematoma. After they have been clamped and tied with fine catgut, the cord is dissected free and the vas deferens is isolated with a few veins and the spermatic artery. Gessner, of New Orleans, has recently shown experimentally that if the spermatic artery is tied the testicle eventually becomes functionless. The excessive length of the veins is then resected as described above, the testicle being elevated by tying together the ends of the ligatures of the stumps. The scrotum is sutured with a con-

tinuous mattress stitch of medium catgut. The mattress suture prevents the turning in of the margins of the scrotum. It is best to reënforce this with a few interrupted sutures of silkworm gut, for catgut may be absorbed too soon. The incision is closed in such a manner as to simulate the median raphe. If each bleeding point is tied there is no necessity for drainage. The wound is dressed in the usual way with sterile gauze held in position by adhesive plaster and a sling or suspensory bandage. The patient should be in bed about a week and should wear a snugly fitting suspensory bandage for two or three weeks longer. This operation not only does away with the veins, but also has the advantage of converting the scrotum into a support for the testicles and thus obviates the necessity of constantly wearing a suspensory bandage.

Hemorrhoids.

Hemorrhoids, or piles, are dilated or abnormal veins or capillaries that form in the lower part of the rectum or in the anus, and are accompanied by excessive connective tissue and thickening of the coats of the vessels involved.

The predisposing causes may be regarded as, first, the upright position; second, the absence of valves in the portal vein; third, the manner in which the muscular coat of the rectal wall is perforated by veins; and, fourth, the lack of a proper support for the blood-vessels in this locality as the mucous membrane is very loosely attached to the submucous coat. The damming back of blood in the portal vein, into which empties the superior hemorrhoidal, is as constant in sitting as in standing. The length of the column of blood must be measured from the lowest extremity of the rectum to the entrance of the

portal vein into the liver and is about fourteen inches. Unlike varicose veins in the extremities, the sitting posture offers no relief, but on the contrary may tend to promote further congestion of the hemorrhoidal veins, as bending the body and pressure on the liver increase the pressure in the portal circulation.

In some families there is a hereditary tendency toward hemorrhoids. Constipation, excesses in diet, straining at stool are causes. Diseases of the heart, liver, or kidneys produce hemorrhoids, particularly diseases of the liver that cause partial obstruction of the portal vein. One of the most significant signs of malignancy in the large bowel, especially in the sigmoid, is the presence of hemorrhoids. When severe hemorrhoids appear in the middle aged or elderly without apparent cause it should always create a suspicion of cancer of the colon or sigmoid, as the contraction from cancer or pressure of a malignant tumor may dam back the blood in the lowest portion of the portal circulation.

Hemorrhoids are classed as external, internal, or mixed. External hemorrhoids arise as a rule from the inferior hemorrhoidal vein and are external to the sphincter. They may give but little trouble. If they become inflamed the pain will be considerable and they should be removed. Often small thrombi occur. As the result of old thrombi or inflammation in external hemorrhoids, tags or projections of connective tissue sometimes form.

The most frequent kind of external hemorrhoids is the thrombotic pile. This usually comes suddenly from exertion, and particularly after straining at stool. The thrombus may be due to breaking the intima of the vein, which permits its lumen to be filled with clots, or to a rupture of the vein itself and the formation of a

hematoma in the surrounding tissues. The size of a thrombotic hemorrhoid varies from one-eighth to one inch in diameter. Usually there is a feeling of something giving away followed by aching. After a few hours or a day, as the clot hardens, the sensation becomes much more disagreeable and the aching and burning may be excessive. If the clot is very small, the symptoms are often insignificant.

The only treatment that affords real relief is incision and turning out the clot. This can be done under local anesthetic, using a half of one percent novocaine solution. After cleansing the mucous membrane and the skin, the tissue over the thrombus is injected and an incision made down to the clot. No matter how the thrombus is situated, the incision should radiate from the center of the anus so as to be parallel with the normal folds. The clot is removed and the cavity packed lightly with gauze, which is kept in position one or two days. Particular care should be taken to cleanse the anus thoroughly with soap and water after each bowel movement. If the clots are multiple and small, the tissue containing them may be excised. The sphincter should not be cut. Usually, however, they are either single or so large that each clot can be opened by a separate incision.

If the clots are left they may be absorbed, but more frequently they become organized into connective tissue, or even calcified, and prove a constant source of irritation. Sometimes the clot is infected and an abscess occurs.

Operations about the anus heal quickly if the ordinary rules of cleanliness and antiseptic surgery are followed, even though it is necessarily difficult or impossible to render the parts surgically clean. Nature has apparently provided some immunity against infection for the tissues here, else wounds would be always infected.

Internal hemorrhoids are usually venous, but may consist of a capillary growth which is small, resembling a raspberry, and bleeds easily, as it is covered by a very thin layer of epithelium. Capillary hemorrhoids do not protrude and can hardly be located by touch. They constitute what is known as the blind, bleeding pile, and bleed readily upon slight contact of instruments on examination. As a rule, the amount of blood lost is never great but the frequent bleeding soon produces marked anemia. The best treatment for this type of hemorrhoid is cauterization, which may be done through a speculum with a Paquelin or electric cautery.

The most frequent form of internal hemorrhoids is that which develops from the superior hemorrhoidal vein just within the sphincter. Often the first symptom is slight oozing of blood; later, there is some protrusion. Bleeding may recur from time to time and may be very slight. This varicose condition is increased by anything that raises the blood pressure in the lower part of the rectum. Constipation or irregular diet will often cause it. Frequently there is no pain except when there is protrusion, and then it is more a sense of discomfort. There is often present, however, a constant sense of weight and dull aching in the region of the rectum. Digital examination will disclose the smooth, velvety feel of partly collapsed hemorrhoids. Reflex nervous symptoms may occur, particularly in patients who are inclined to be neurotic.

Treatment of internal venous and of mixed hemorrhoids is practically the same. If bleeding is frequent and if discomfort is considerable, operation should be performed. However, palliative treatment sometimes cures in the early stages when the disease is mild and if for any reason the patient rejects operation, palliative

treatment should be given. Rest in the horizontal position and cold applications are very beneficial. Often pressure on the anus is effective. In order to lessen the congestion in internal hemorrhoids, it is necessary to change the position of the body so the portal circulation will easily drain the blood from the pelvis. A slight elevation of the foot of the bed may be necessary. Enemas of cold water and careful regulation of the bowels should be recommended. Alcohol must be prohibited or curtailed in amount. The patient must take some exercise in the open air and the bowels be induced to move at a regular time every morning. Cold baths after arising are beneficial. If the bowels are constipated, mild cathartics such as cascara are given. If hemorrhoids tend to prolapse, they should be cleansed thoroughly before being returned and some ointment or solution applied. Suppositories are not satisfactory because they slip above the region of the hemorrhoid. Occasionally passage of a rectal bougie of full size once a day and allowing it to remain in the grasp of the sphincter for five or ten minutes will overcome spasm.

Operative treatment, which should be the regular treatment for hemorrhoids that develop sufficiently to give considerable discomfort, may be the injection method, ligature, excision, or clamp and cautery. The injection method formerly had considerable vogue but has now rather fallen into disrepute. In certain cases, however, where there are only one or two isolated hemorrhoids and when the sphincter is relaxed, the injection method if properly used often gives satisfactory results. The size of the hemorrhoid is no contraindication to this operation. Formerly too strong a solution was used and very disagreeable results would follow. Tuttle's modification of Shuford's solution is probably the best.

This consists of two drams of Calvert's carbolic acid, one-half dram of salicylic acid, one dram of biborate of soda, and glycerine, a sufficient quantity to make one ounce. The fluid should be perfectly clear. If milky white it is due to imperfect solution and should not be used until it becomes perfectly clear. The amount of this solution to be injected into any individual hemorrhoid depends upon the size; from two to ten minims are sufficient. The injection can be made with the ordinary hypodermic syringe. The anus is cleansed and the hemorrhoid drawn down into view. The index finger of the left hand is introduced into the anus and a hypodermic needle is inserted at the lowest part of the hemorrhoid and carried well toward its center. A small amount of the solution is slowly injected while moving the point of the needle backward and forward to distribute the injected fluid. The needle is left in position for one or two minutes to prevent the solution escaping from the puncture, and is then withdrawn. A small piece of cotton soaked in alcohol is placed over the puncture immediately after the needle is withdrawn. The hemorrhoid is kept outside the sphincter for a few minutes in order to prevent forcing the solution elsewhere. After it is reduced a small compress is placed upon the anus, secured by a T-bandage, and the patient is required to lie down for ten or fifteen minutes. The day after the injection the pile will be found to consist of a tense, hard mass which in a few days begins to shrivel, and if the treatment is successful it eventually disappears. There is but little pain if the injection is properly done. The bowels should be confined for forty-eight hours and then moved with a simple laxative or a cold water enema. A great many cases can be cured in this manner at the office that would not submit to a more radical procedure.

While this method should only be employed when the sphincter is weak and when there are only one or two hemorrhoids, and while it does not always result in a cure, it has a field of usefulness.

Before an operation for hemorrhoids, the patient's bowels should be thoroughly moved by a dose of oil taken the day before and by an enema five or six hours before the operation. Before applying any operative procedure except injection, the sphincter must be thoroughly dilated. This is best done with the finger and thumb, gently stretching and massaging the sphincter so its paralysis is gradually accomplished. In this way neither the sphincter nor the mucous membrane is torn, which is often the case with too forcible dilatation. In the ligature operation, after cleansing the hemorrhoid thoroughly and using some antiseptic solution, such as boric acid or weak bichloride, the pile is caught in forceps and an incision made with scissors at Hilton's white line where the skin and mucous membrane join. The pile is dissected from below upward, partly with scissors and partly with dry gauze, using as little force as possible, and getting the pedicle down to a small piece of tissue. The pedicle is tied firmly with silk or linen and the hemorrhoid cut off not too close to the ligature. Each pile is treated in a similar manner. This can often be done under local anesthesia.

The excision operation, which is based upon the method of Whitehead, has been variously modified, and consists of excision of the pile bearing area. An incision is made around the anus following closely Hilton's white line. The mucous membrane is dissected up until all of the piles can be drawn down without tension. The whole lower cuff of the pile bearing area of mucous membrane is excised by cutting a short distance and immedi-

ately suturing. This prevents retraction of the mucous membrane. Tuttle has modified this operation by merely making an incision at the posterior portion of Hilton's line and then bluntly dissecting free the mucous membrane from this incision. There are many other methods of excision. In Earle's operation the pile is clamped by special forceps of his device. It is cut away and sutures are placed around the forceps including the pedicle of the pile. After the sutures are placed the forceps are removed and the sutures tied. In any method the skin should not be caught, as it is unnecessary and makes convalescence much more painful.

The most satisfactory operation, as a rule, for hemorrhoids and one that has well stood the test of time is the clamp and cautery. If carefully performed it should not result in stricture. Ligature methods are followed by a certain amount of necrosis and in excision the sutures must necessarily be bathed in fecal contents, but the great advantage of the clamp and cautery is that the heat sterilizes the tissues and also seals the wound with an aseptic eschar. The operation is simple, though it should be carefully done in order to secure the best results. After thoroughly dilating the sphincter each hemorrhoid is caught at its apex with a hemostat. It is dragged well down into the wound and clamped with Ferguson's pedicle forceps parallel with the anal folds. These forceps have blades that are flat and hold the hemorrhoid firmly. No skin should be included within the bite of the forceps. It is best not to make an incision with scissors or knife because this leaves a raw surface that may be a portal of infection. The object of the clamp and cautery operation should be to leave nothing that is not thoroughly covered with an eschar. With a little care a good hold can be obtained upon the hemorrhoid

without including the skin. All of the hemorrhoids are caught with Ferguson's clamps in a similar manner. There are rarely more than three. After all the piles have been clamped, the last one clamped is pulled down so the tip of the Ferguson forceps emerges from the

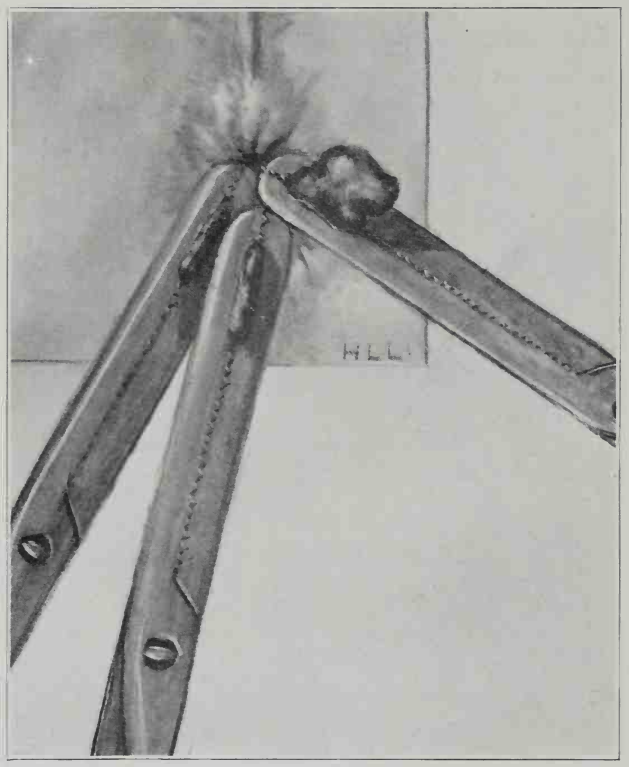

Fig. 79.—Three hemorrhoids have been clamped with Ferguson forceps, two having been cut away while the third is still in the grasp of the forceps. Each forceps should be surrounded by wet gauze and the base of the hemorrhoids thoroughly cauterized.

anus. A small piece of wet gauze is wrapped around the base of the hemorrhoid just beneath the forceps. This protects the surrounding tissues from heat. The pile is cut off about one-fourth of an inch from the forceps. This can be done with the Paquelin cautery. The stump

is then thoroughly burned, taking at least one-half minute in order that the pedicle contained in the grip of the forceps is cooked by the heat. The wet gauze is then removed and the next hemorrhoid is treated in a similar way. After cauterizing the hemorrhoid, the forceps are not removed but are merely returned to such a position as is least in the way. This is usually accomplished by

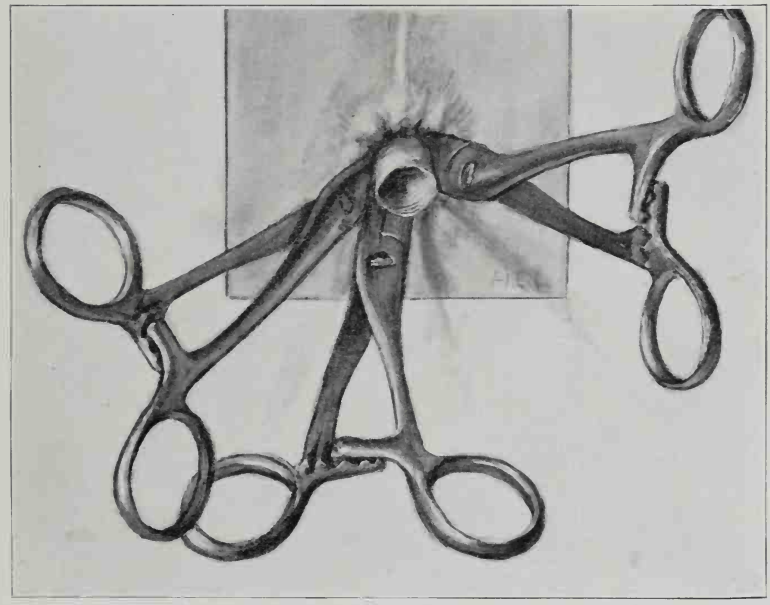

Fig. 80.—Hemorrhoids have been removed, the pedicles cauterized, and the forceps have been replaced within the anus. The rubber tube is in position. The forceps can now be gently released without disturbing the eschar.

placing the tip of the forceps in the rectum and shoving the pedicle in its grasp gently up into the rectum (Figs. 79 and 80). After the last hemorrhoid is cauterized a rather firm rubber tube about three inches long and one-third of an inch in diameter is anointed with sterile vaseline and inserted into the rectum. A safety pin is fixed in its outer end. Then each Ferguson clamp is removed gently so as to avoid breaking up the eschar.

The parts are thoroughly dusted with bicarbonate of soda and sterile gauze is wrapped around the outer end of the tube under the safety pin to prevent the safety pin from pressing on the anus. More gauze is placed and a T-bandage applied. If care is taken in the cauterization as has been mentioned, there is practically no danger of hemorrhage because the tissue is cooked well down into the grasp of the forceps. There is no danger of stricture because an ample amount of healthy mucosa is between each forceps, and at the same time the contraction of the scar from the burn, which is notoriously greater than from an incision, tends to obliterate still further any varicose vessels in the neighborhood. The tube gives exit for gas and makes the patient more comfortable. If for any reason there is bleeding, it will appear at once through the tube.

The after-treatment consists of rest in bed for several days, preferably three or four days at least, and morphine if the pain is severe. About the third day after operation an enema of several ounces of sweet oil is injected through the tube and the tube clamped and allowed to come away. The skin around the anus should be kept clean. If there is not much irritation a dry dusting powder is used. If the irritation is disagreeable, some ointment or carbolated vaseline can be applied. The bowels should move regularly after the third day. A laxative is given in order to insure that the movements will be soft. The patient may leave the hospital within a week or ten days, or in the simpler cases even earlier. There is always swelling for the first few days after an operation of this type and the patient should be informed before the operation that this will occur. The swelling gradually disappears and the redundant tissue is usually taken up within a few weeks

or at least a few months. If, however, any unnecessary tags of skin are left after several months they may be readily removed under a local anesthetic.

A great many rectal operations are done under local anesthesia, even the clamp and cautery operation. The sphincter can be dilated and a ligature applied in patients who are not too nervous. The anesthetic should be one-half of one percent novocaine solution. One finger is passed into the anus and the hypodermic needle inserted first about one inch back of the posterior margin of the anus. The solution is injected quickly, the needle being carried up first on one side and then on the other and the injection made just beneath the skin and not into it. The point of the needle is guided partly by the finger in the rectum. Both sides are injected from the same puncture. After as much tissue has been infiltrated as possible, the needle is withdrawn and reinserted at the upper limit of the injected area first on one side and then on the other until the anus is completely surrounded. The injection may then be made somewhat deeper. It will be found that in many cases the sphincter can be dilated and hemorrhoids excised after local anesthesia of this type with practically no pain.

CHAPTER XVI.

TRANSPLANTATION OF THE ANTERIOR TEMPORAL ARTERY.

Occasionally defects of the cheek, caused by accidents, or as a result of operation for malignant disease, or from a gangrene, are so extensive that plastic correction is exceedingly difficult. The margins of the defect are fixed to the bone and do not permit much stretching. If flaps are taken from the arm, the character and texture of the skin is so different from the skin of the face that the contrast is very noticeable. Then, too, it is frequently necessary to have an epithelial lining on the inside of the mouth, and though a mucous membrane lining is preferable to one of skin, it is often impossible to secure mucous membrane.

Flaps from the forehead are used to remedy these defects, and are taken with the pedicle either from the temporal region or from the middle of the forehead. This, of course, necessitates cutting the pedicle later and returning it to its original position. If the anterior temporal artery is included in the pedicle, the flap is thus deprived of an important blood supply. Frequently flaps that cover defects of the cheek obtain their sole nourishment around the edges, and if a flap has also been turned in to make a lining, there is a still greater demand upon the external flap for blood supply. Dunham, of New York, has met this objection by dissecting the temporal artery from the flap after the flap has healed in its new position and returning the pedicle minus the artery. This, of course, is an improvement, but it necessitates

two operations and the dissection of the temporal artery from the transposed and infiltrated pedicle is more difficult than a dissection from the normal tissue at the original operation.

On two occasions the author has transplanted the anterior temporal artery, dissecting it free from its origin to the margin of the proposed flap.

The anterior temporal artery presents peculiar advantages for transplantation. It is not essential to the nourishment of the forehead or scalp, which has an abundant anastomosing blood supply. It is tortuous and when dissected free, even with some surrounding tissue, it may be straightened and will reach much farther than before dissection. This permits placing the flap in positions distant from the origin of the artery, and the maintenance of an abundant blood supply.

The patient should be prepared for rectal anesthesia according to the method of Gwathmey. The bowels are opened by a dose of oil the night before, followed by soap sud enemas two to three hours before the operation. An hour before the operation a suppository of five to ten grains of chlorotone is given. A hypodermic of a quarter of a grain of morphine and 1/120th of a grain of atropine is administered a half hour before the operation, and the injection of oil and ether is begun slowly about ten minutes later. The mixture consists of pure olive oil and ether varying from equal parts in children, to three parts of ether and one of oil in cases difficult to anesthetize. In adults, usually two parts of ether to one of olive oil is a satisfactory mixture. The amount injected is one ounce of the mixture to every twenty pounds of body weight, but in any case it should not exceed eight ounces of the seventy-five percent solution of ether in oil. This is given slowly in the room, with the patient turned

on his left side, and should take from five to ten minutes. The patient usually goes under the anesthetic gradually. If anesthesia seems too profound, especially as indicated by cyanosis and disturbance of the respiration or by a

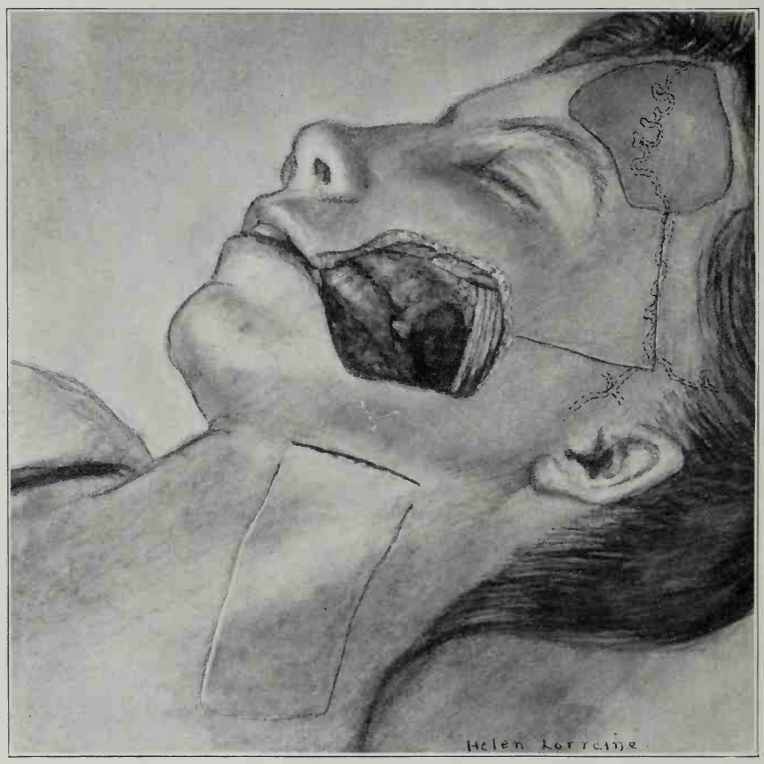

Fig. 81.—First step of transplantation of the anterior temporal artery with a frontal flap. Outlines of the flap on the neck and of the frontal flap, together with the incisions for dissecting out the anterior temporal artery, and for burying it in its new location are shown.

bad pulse, some or all of the mixture can be withdrawn through a rectal tube. About five minutes before the operation is concluded all of the mixture is withdrawn, the rectum and sigmoid are irrigated with cold water, and several ounces of pure olive oil are slowly injected and allowed to remain. This anesthesia in the author's

hands has been most satisfactory for surgery of the neck, for plastic work about the face, and particularly for such an operation as transplantation of the anterior temporal artery.

Fig. 82.—The flap on the neck has been dissected free and drawn under the bridge of skin separating its base from the defect in the cheek. The artery has been partially dissected. Insert shows a section of the artery with ligation of posterior temporal artery when necessary to secure greater length.

The cheek is prepared for the new flap by trimming away the scar tissue along the margins of the defect and by undermining the skin slightly. The position of the flap to be transplanted is outlined on the forehead with the point of a knife, going as near to the hair line as possible. An incision is made over the region of the an-

terior temporal artery, extending from its origin to the point at which the artery enters the proposed flap. This incision should be straight, no matter what the course of the artery. Great care is taken not to injure the artery

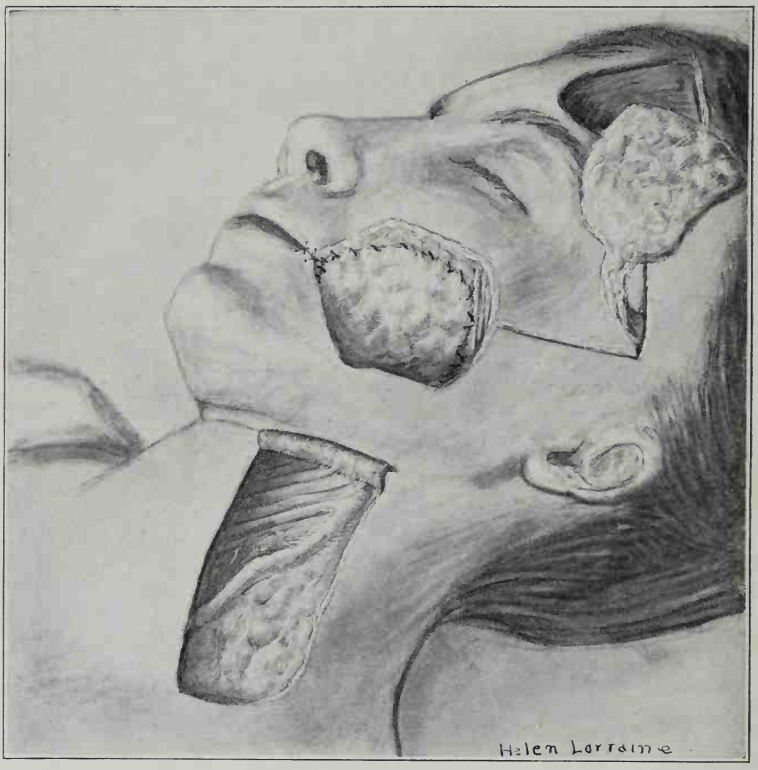

Fig. 83.—The flap from the neck has been sutured in position. The anterior temporal artery and frontal flap have been freed, and are ready to be transplanted.

and not to grasp it with forceps. It can be easily handled by picking up the tissue around it with delicate thumb forceps. Considerable tissue is included with the artery in order not only to avoid injury to the artery, but also to preserve its nerve supply. After the artery has been freed, the flap is cut and placed in position.

This gives an idea where the artery shall be buried (Figs. 81, 82, 83 and 84). The flap is covered with cloths wrung out of warm salt solution and an incision for burying the artery is made just through the skin. The

Fig. 84.—The anterior temporal artery with the frontal flap has been transplanted and the flap sutured in position. The raw surface left on the forehead has been diminished by sutures at its angles.

margins of this incision are undermined freely, but not too deeply. In this way the branches of the facial nerve are not injured. The flap is placed in position and fastened with a few sutures. It should not be sutured too tightly, because the flap has too much nutrition and unless there is some point where the excess of blood

can ooze out for the first day or two, the tension in the flap from the arterial pressure may be so great as to cause partial necrosis. A few stabs in the flap also relieves the venous congestion. This, in fact, is the chief danger, not too little but too much blood supply. If it is necessary to have an epithelial lining, a flap may be turned up from the neck and sutured with the skin side toward the cavity of the mouth before the anterior temporal artery is transplanted. The illustration shows the manner of doing this. Or, if the defect is not too large, mucous membrane from the tongue, as suggested by Willard Bartlett, can be used.

By the second day the flap is swollen and becomes a dark purple color. If it is too tense every few hours a sharp knife can be inserted in the stab wounds or along the edges of the flap to scrape it a little to promote bleeding and relieve the tension. After a week the swelling begins to disappear and the new venous capillaries drain away the blood. The efficiency of the artery can be demonstrated months after the operation by pressing upon it and noting the change in color of the flap.

In two cases in which this operation was done the artery has remained patent and is pulsating several months after the operation. In the first case, all of the flap took. In the second, a middle aged woman in poor health, about two-thirds of the flap sloughed away on account of excessive passive hyperemia.

The first case, Mr. W. H. D., aged 22 years, was injured on February 2, 1914, by a shot gun while trying to quell a disturbance among the laborers of a mine of which he was superintendent. The gun was discharged at short range and blew out his left eye, a good portion of the left maxillary bone, and the septum of the nose, together with the soft tissues over the cheek. The ac-

Fig. 85.—Photograph of H. D. about three weeks after the injury, showing a large cavity communicating with the nasal fossa.

Fig. 86.—Photograph of H. D. three weeks after operation in which a frontal flap with anterior temporal artery attached was transplanted to cover the defect. Note the incision for dissecting the artery and also incision for burying it. The artery can be distinctly felt pulsating in its new bed.

companying photograph shows his condition about three weeks after the injury. A large cavity was left connected with the nasal fossa (Fig. 85). This was closed by transplanting from the forehead a flap with the anterior temporal artery. The technique was as described above. All of the flap took. The photograph taken about three weeks after this operation shows the line of incision for dissection of the artery and also the incision under which the artery was transplanted (Fig. 86).

Mrs. S., aged 47 years, was referred to the author for a recurrent cancer of the cheek. She had been operated

Fig. 87.—Photograph of Mrs. S. about three weeks after removal of recurrent cancer of the cheek with Paquelin cautery. The tongue, alveolar process, and some denuded bone can be seen.

upon a few months before by another surgeon and as recurrence was prompt and the glands of the neck were involved the prognosis seemed bad. A block dissection was first done on the upper part of the neck, removing glands, fat and fascia in one mass. The cancer in the cheek, which was about an inch and a half in diameter,

Fig. 88.—Mrs. S. The defect in the cheek practically closed. About two-thirds of the frontal flap sloughed away, but enough remained to close the upper portion of the wound.

Fig. 89.—Mrs. S., with eyes closed, showing there is no paralysis of any branch of the facial nerve.

was then excised with a Paquelin cautery. The photograph shows the condition about ten days after this operation (Fig. 87). The defect was, of course, extensive and the deformity great. A flap of skin was turned under as shown in the accompanying illustrations, and sutured to the wound with the skin surface inward. The anterior temporal artery with a flap from the forehead was then transplanted as in the previous case. The flap became purple and tense, but on scraping its edges and letting out some blood its color would again become normal. The growth of capillaries was poor, and about two-thirds of the flap sloughed off on account of the intense passive hyperemia. To the well nourished remnant, however, flaps from neighboring tissues were later attached and grew satisfactorily. The photographs show her condition before and after the plastic operations (Figs. 87, 88, and 89).

NOTE.—Since the page proof has come, the attention of the author has been called to the fact that Dr. George H. Monks, of Boston, transplanted the anterior temporal artery with an attached flap to restore the lower evelid, and reported the operation in the *Boston Medical and Surgical Journal* of October 20, 1898. The author was unaware of the work of Dr. Monks. While the operation described in this chapter differs in several details, the principle involved is the same, and, of course, Dr. Monks is entitled to priority.

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